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The Editor begs to state that the Authors are alone responsible for the facts and opinions contained in their respective papers.

JAMES BARCLAY MURDOCH, F.R.Ph.S.E.

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TRANSACTIONS

OF THE

GEOLOGICAL SOCIETY OF GLASGOW.

No. I.—Notes on Cone-in-Cone Structure. By John Young, F.G.S., *V.P.* With Illustrations. [Plates I. and II.]

[Read 12*th March*, 1885.]

Having for a considerable number of years collected all the varieties of the remarkable structure known as Cone-in-cone which have come under my observation on the excursions of this Society to different localities within the bounds of our Western Scottish coalfield, and having recently obtained many beautiful and interesting examples from a locality first brought under notice by Mr. Robert Craig, corresponding member, Langside, Beith, I intend, in the following notes, to offer some remarks on these and other Scottish specimens, as presenting points of structure, and other external and internal characters, which, in the descriptions that I have met with, do not seem to have been noticed, or if observed have not been properly understood, but which, I think, when rightly interpreted, will lead to more correct explanations of this structure than any that have been advanced.

Before describing these specimens, however, I shall here shortly refer to the several descriptions which I have been able to obtain from those authors who have formerly noticed Cone-in-cone structure, and for some of these references I am indebted to our Honorary Associate, Prof. J. W. Judd, London, whom I here thank for the trouble he has kindly taken for me in this matter.

The first notice I find is one by the Rev. David Ure, M.A., in his "History of Rutherglen and East Kilbride, 1793," where he states, p. 253, "The most uncommon variety of till in this

country is one that, by the miners, is called *Maggy*. It is incumbent on a coarse ironstone, or doggar, at Mauchlanhole and Torrance, and is generally found in the shape of cones, as pl. xx., fig. 8. These cones are of a dirty black colour, and are composed of concentric lamellæ of various thickness, and which may be separated from one another, exhibiting surfaces adorned with small but irregular undulations. The apices of the cones, which are of various dimensions, rest upon the stone, and the bases are lost in the surrounding till. They are softest at the base, but gradually increase in hardness towards the apex. The whole, however, is in general very hard. This curious fossil contains, along with clay, a considerable proportion of iron and lime, and perhaps some other substance which co-operates in the formation of its peculiar figure." In the plate to which Ure refers, the specimen has been drawn upside down, as the apices of the cones should be downwards, as he correctly describes them, but not upwards as shown in the figure. There is no mistaking in the clear description given that he is referring to Cone-in-cone structure.

The second notice is contained in the Report of the British Association for 1859, where there is a note, p. 124, "On the origin of Cone-in-cone," by H. C. Sorby, F.R.S. He says that "Cone-in-cone is met with in so many stratified rocks that most geologists must be familiar with its general characters, though no one appears to have thoroughly investigated it or to have given any very satisfactory explanation of its origin. The cones often occur in bands parallel to the stratification of the rock, their apices starting from a well-defined plane, and after extending upwards or downwards for a greater or less distance, with their axes perpendicular to the plane of the stratification, they end in bases parallel to it, but not all at the same exact level, some standing up above the general surface. They are not perfect cones, but are of such forms as would result from the varied interference of surrounding cones, and from the development of others within their own substance. On examining their transparent sections with a low magnifying power under polarized light, the author had been able to ascertain that this peculiar structure is intimately connected with some kind of oolitic grains. In the formation of the most abundant variety of oolitic grains small prismatic crystals of more or less pure carbonate of lime were deposited around a

nucleus in nearly the same amount on all sides so as to give rise to irregular ovoid bodies, whereas in the formation of Cone-in-cone very similar crystals were deposited almost entirely on one side, along the axis of the cones, in such a fan-shaped manner as to give rise to their conical shape. In the thin sections of some specimens every connecting link between imperfect oolitic grains and genuine cones can be seen to great advantage with polarized light. The growth of the cones did not, however, proceed without interruption, for other smaller fan-shaped groups were developed within the larger; and thus by the mutual interference of contiguous groups and of others contained within themselves there was formed a mass of irregular cones enclosing other cones." "The author concludes that this structure is one of the peculiar forms of concretions, formed after the deposition of the rock in which they occur, by the crystallization of the carbonate of lime and other isomorphous bases."

The third notice is that quoted by Prof. A. Geikie in his "Text-Book of Geology, 1882," where he states, p. 313, that "Prof. Marsh suggests that the complex structure known as 'Cone-in-cone' may be due to the action of pressure upon concretions in the course of formation." (*Proc. American Assoc. of Science*, 1867.)

The fourth notice is contained in an appendix to Dr. Dawson's "Acadian Geology, 1868," in which there is a note, pp. 676-77, on what are termed "Cone-in-cone concretions." In writing of these, Dr. Dawson says, "In these nodular layers also, as well as in certain layers of hard argillaceous matter, we often find the remarkable structure to which this note relates. It consists of a series of conical forms often running together into rows and ridges, and consisting of a series of concentric coats, whence the name 'Cone-in-cone,' given by the miners. The surfaces of the coats are also curiously marked with transverse ridges giving a wrinkled appearance, so much resembling some organic structures as to deceive some persons into the belief that these curious forms may be fossils." Dr. Dawson further refers to specimens sent him, one of which he figures, but like that given by Ure, to which I referred above, the figure is also drawn upside down. In exhibiting these specimens to the Natural History Society of Montreal, he states his belief that they are produced by "concretionary action proceeding from the surface of a bed or layer, and modified by the gradual compression of the material."

The fifth notice is to be found in the "Students' Manual of Geology," by Professor J. Beete Jukes, third edition, edited by Professor A. Geikie, 1872. At p. 312 it is stated that "some clay ironstones exhibit another concretionary form called 'Cone-in-cone,' as the seam of ironstone breaks into conical forms with the bases of the cones at top and bottom of the seam, and their apices pointing inwards towards each other. The surfaces of these cones are corrugated by small horizontal fretted wavelets, or ridges, rather resembling those on the outside of some stalactites, and each cone is concentrically enveloped by several coats, the surface of each being similarly corrugated. Some coals also exhibit a curious structure in the interior, somewhat analogous to this, showing, when parted, a series of narrow winding corrugated ridges and furrows, about an inch wide and deep, fitting closely into each other till separated with some little force."

The sixth notice is by R. Daintree, F.G.S., in a paper on the Geology of Queensland, *Quarterly Journal Geol. Soc.*, vol. xxviii., 1872, where he makes a short reference to "Cone-in-cone," and gives an analysis. At page 282 he says, "One other peculiarity in the strata forming the series is the presence at intervals of thin layers of limestone having the well-known Cone-in-cone structure. This has more the appearance of a chemical precipitate than a mechanical deposit, and contains no fossils." Its analysis gave—

Insoluble in hydrochloric acid, ...	14·920
Ammonia precipitate, ...	4·860
Carbonate of lime, ...	75·458
Undetermined constituents, ...	4·762
	100·000

The seventh and last notice which I have obtained is to be found in the *Quarterly Journal Geol. Soc.*, vol. xxix., 1873. At p. 418 there is a short discussion on some peculiar striated markings in chalk, which were thought by some to be of organic origin. "A note was read by Mr. Whitaker from Mr. Judd, who held that these specimens were not due to any organic origin, and that the structures known as 'Cone-in-cone,' or 'beef,' which he terms 'quasi-crystalline structures,' seemed to him to be closely related."

From these quotations it will be seen that the descriptions of Cone-in-cone structure are somewhat varied and conflicting—one

author ascribing it to concretionary action, the result of a kind of quasi-crystallization; another to the action of pressure on concretions in the course of formation; and a third to chemical precipitation. None of them, however, notice all the characters to be seen in Cone-in-cone, at least as revealed in the best-preserved Scottish specimens; and I think, after careful examination, that these clearly indicate other agencies at work in the formation of the structure, the actions of which were totally different in character and in time from those heretofore noticed.

The specimens of Cone-in-cone which seem to throw new light on the origin of the structure were obtained from an old open-cast quarry at Waterland, near Lugton station, Dunlop, Ayrshire, and, as formerly stated, were first brought under the notice of the Society by Mr. R. Craig. In this quarry the main seam of clay-band ironstone of North Ayrshire is brought to the surface through the action of a fault. In other localities in Ayrshire, as well as in Renfrewshire and North-west Lanarkshire, this ironstone has been, during recent years, extensively mined in numerous pits throughout these districts. Its geological position is in the group of lacustrine strata that here separates the upper from the lower division of the Carboniferous limestone series of Western Scotland. The Cone-in-cone stratum in the Waterland Quarry is seen to rest directly on the clay-band ironstone, and forms a thin band seldom exceeding four inches in thickness, the average being from one to two inches. It is overlaid by a bed of soft, black, carbonaceous shale, and this again by strata of flaggy sandstone. The Cone-in-cone stratum on this horizon has been found extending, but somewhat irregularly, along with the ironstone, over nearly the whole tract of country in which the ironstone has been worked, and this embraces places more than twelve miles apart; but the two localities that have yielded the best preserved examples are the quarry at Waterland and one of the pits near Paisley. The Cone-in-cone stratum parts readily from the ironstone, as well as from the overlying shale, and in the quarry at Waterland is found in small slabs, lying on the shale heap, where it has been cast aside during the working of the ironstone. Through the action of the weather, both the upper and lower surfaces of these slabs have been cleaned of the most of the adherent shale, and they reveal the interesting fact that in this instance the Cone-in-cone stratum has been originally a thin bed of stratified shale, composed in great bulk of the calcareous

shells of Entomostraca, of the genera *Carbonia*, *Leperditia*, and *Beyrichia*, of species frequenting lacustrine waters. This is confirmed by the circumstance that in a pit near Lugton station, about a quarter of a mile distant from Waterland Quarry, as well as in pits near Dalry in which Cone-in-cone structure in this stratum is absent, or only very feebly developed, the shale exists as a finely-stratified deposit, every layer being crowded with Entomostracan shells. Where the Cone-in-cone structure has been best developed, the Entomostraca are almost entirely obliterated, not a trace of them being seen, except in some few specimens, where they occur on both the lower and upper faces, but not in the central portion of the bed. Along with these organic remains, the stratum also contains a few scattered coprolites, and scales and teeth of small ganoid fishes. Coprolites are also found in the clay-band ironstone, but both in it and the overlying black shale the Entomostraca are almost entirely absent.

When newly fractured, the Cone-in-cone stratum is of a black colour; but under the influence of the atmosphere it weathers into a yellowish-grey rock. It is strongly calcareous, but does not contain much iron, and for this reason it is thrown aside in the workings as of no value. It contains a small amount of hydrocarbon, probably derived from the organisms once contained in the bed, and to which its dark colour is chiefly due. The more highly calcareous condition of the Cone-in-cone stratum, over that of the underlying clay ironstone and the overlying black shale, may be accounted for by the abundance of the Entomostraca originally contained in this bed. These organisms, in their decay, would naturally give off carbonic acid and other gases, and these would act upon the carbonate of lime of the shells, and in time would naturally dissolve it; the resulting calcareous matter combining with the clay of the deposit, and ultimately forming the material out of which the Cone-in-cone structure has been elaborated.

Mr. J. Holms Pollok, of the Chemical Laboratory, University, Glasgow, has kindly made for me the following analyses of specimens:—1st, Cone-in-cone from Waterland Quarry (No. 1 specimen). 2nd, two analyses of No. 1 specimen to find the difference in the amount of lime present between the bottom and the top layers of the cones—it having occurred to me, in accordance with the theory which I hold of this cone formation, and to which attention will be directed in a subsequent portion of this paper, that

if the lime was partly due to the dissolving action of carbonic acid upon the shells and other organisms of the deposit, it ought to be more abundant in the calcareous sediment forming the upper portion of the cones than in the sediment at the base. This view, I am glad to say, is borne out by the analyses. 3rd (No. 2 specimen), Entomostracan shale from Lugton pit, near Waterland, in which the cone structure is not developed. 4th (No. 3 specimen), clay-band ironstone from Waterland Quarry, on which the cone stratum immediately rests, but downwards into which it does not extend.

Cone-in-cone (No. 1 specimen). Waterland Quarry.	
Silica, etc.,	14·60
Organic matter,	?
Water,	1·83
Ferrous Oxide,	1·30
Ferric Oxide,	——
Manganese,	Trace.
Alumina,	2·37
Lime,	39·95
Magnesia,	·90
Potash and Soda,	1·25
Carbonic Acid,	37.00
Sulphuric Acid,	·50
Phosphoric Acid,	——
	99·70

Cone-in-cone (No. 1 specimen).	Lime present.
Upper portion of stratum,	47·14
Lower portion of stratum,	38·60

Entomostracan Shale (No 2 specimen). Lugton Pit.	
Silica, etc.,	48·58
Organic matter,	·76
Water,	6·40
Ferrous Oxide,	2·12
Ferric Oxide,	2·57
Manganese,	Trace.
Alumina,	3·19
Lime,	13·80
Magnesia,	1·00
Potash and Soda,	1·70
Carbonic Acid,	14·40
Sulphuric Acid,	2·08
Phosphoric Acid,	2·31
	98·91

Clay-Band Ironstone (No. 3 specimen). Waterland Quarry.

Silica, etc.,	13·41
Organic matter,	·85
Water,	2·47
Ferrous Oxide,	36·90
Ferric Oxide,	2·20
Manganese,	Trace.
Alumina,	·60
Lime,	6·45
Magnesia,	2·70
Potash and Soda,	——
Carbonic Acid,	33·30
Sulphuric Acid,	1·00
Phosphoric Acid,	——
	99·88

Having stated, thus shortly, the conditions under which Cone-in-cone occurs at Waterland, I shall now proceed to describe its external and internal characters, as displayed by specimens from that locality, and afterwards I shall endeavour to describe what I believe to be some of the conditions under which the structure itself was formed. In order, however, to illustrate what I have to state—first, regarding the external form of the cones, and, second, their internal structure—I may mention that I have used for the first proposition specimens in which the cones have been fractured vertical to their length, and in which the transverse corrugations are well seen on the surface; and for the second, upwards of two dozen vertical sections selected from different specimens, and ground to a thin transparency, so as to show the internal structure of the cones throughout all their length, from their commencement to their finish, as well as the variations in development which exist between the cones of one specimen and those of another. Upon these sections I rely strongly, as supporting the conclusions I had previously formed from the study of the external characters of Cone-in-cone structure in specimens showing only the outer surface.

In the first place, I may here state, in regard to the form and arrangement of the cones, that there can be no doubt of the fact, as seen in my specimens, that the apices are invariably turned to the under or lower side of the stratum, while their bases are as invariably directed to the upper surface. I have never

seen any specimens of Cone-in-cone to justify the statement, quoted from Geikie's edition of Jukes' Manual of Geology, that the bases of the cones are "at top and bottom of the seam, and their apices pointing inwards towards each other." I am inclined to think that such a description is due to faulty observation, or could only have been made from a badly-preserved specimen, in which the structure was obscure or much confused. From the quotation given from Dr. Sorby's paper, it seems to me that he also has fallen into a similar mistake when he states that the apices start "from a well-defined plane, and after extending upwards or downwards for a greater or less distance, with their axes perpendicular to the plane of stratification, they end in bases parallel to it." I hope to show by and by that such an arrangement of the cones, as illustrated in my specimens, does not exist, and could not take place, as the action was one which proceeded upwards from the base of the stratum, and terminated ultimately on the upper surface of the bed.

In transparent sections of Cone-in-cone from Waterland, the apices of the cones are seen to terminate downwards at distances varying from one quarter to one half inch above the lower surface of the bed. Below the point where the cones terminate, the bottom layer has a confused, undulating structure, in which the original stratification of the deposit is in most cases obliterated, but at the point where the cones commence, the sections show the beginning of a great number of very small cones—in fact this layer is crowded with them—the bases ascending to varying heights in the stratum, only a limited number of the original cones having ever reached the surface of the bed, and these main or leading cones form a marked feature in all the sections.

The cones in transverse sections are all more or less circular, and of slightly varying diameters, and are formed of successive concentric layers, one within another, throughout the whole length of each cone. Transparent sections show that the lower external layers of the cones never reached the surface of the stratum as it now exists, but that they, in their expansion upwards, interfered with and impinged upon one another, in most cases terminating at the same level; these successive ascending layers, in their junctions with one another, forming a kind of arcading that reminds one of miniature gothic arches. It is very probable that it is this arching, formed by the upward junctions of the layers in the several cones,

which has deceived some observers into the belief that there were two sets of apices dovetailing into each other, viz.—the true apices, and the pointed arches formed by the junction of the ascending layers, but it only requires an examination of vertical transparent sections to show that such was not the case.

Nearly every author who has written upon Cone-in-cone structure has referred to the transverse corrugations seen on the surface of the several layers of the cones, but in none of the descriptions that I have read has any explanation of these corrugations been given, nor is any notice taken of a thin film of clay which also coats the vertical surface of these concentric layers, and to which their ready separation from one another is due. I have found that this thin coating of clay exists in all the Cone-in-cone specimens that I have been able to examine, and in the transparent sections from Waterland it is seen to mark off the several calcite layers from one another, by nearly opaque black lines of clay of varying thickness. Sometimes the clay coating is of extreme thinness, at other times it is as thick or thicker than card paper ; but thick or thin, it always has a tendency to form weak lines between the layers, and to cause in them a ready vertical separation of the cone structure in most instances. Tangential, or cross sections of the cones, especially when taken near the surface of the bed, also show very clearly this film of black clay, in thin, ring-like lines, surrounding the concentric layers. I shall again refer to this important character when stating what I believe to be the mode of formation of the cones, and shall now only notice shortly one other external character exhibited on the surface of our best-preserved specimens.

In many of the specimens from Waterland, as well as in those from the pit near Paisley, if we examine the upper surface of the Cone-in-cone stratum, we see that the bases of the cones terminate in a series of small, ring-like elevations, one within another, the innermost being generally the highest and often less than a line in diameter at its summit. These small cones vary from one to six or more in number within the base of each larger cone, and they often rise from one eighth to one quarter inch in height above the general level of the stratum. These little elevations are seen in the transparent sections to be the bases of smaller cones, the apices of which, like those of the larger ones, are always directed downwards in the stratum. In some of the specimens that I exhibit, and which have weathered for some time upon the shale heaps at the quarry, the

small inner cones have in many instances fallen out from the bases of the larger ones. In these specimens the surface of the cone stratum presents the appearance of small groups of irregular, ring-like, conical craters, strongly reminding one of the appearance of the moon's surface as seen in photographs, a resemblance which has, independently, suggested itself to different observers of these specimens.

I have no doubt that the characters here indicated were present on the surface of every Cone-in-cone stratum, but it is only when preserved under perfect conditions like those from Waterland that these small terminal cones are ever seen, they being generally adherent to some hard, overlying bed, to which the stratum is firmly attached, and by which the bases of the cones are concealed.

Thus far I have endeavoured shortly to describe some of the external and internal characters observable in the specimens of Cone-in-cone from Waterland Quarry, and I shall now proceed to refer to what I believe were the agencies that originated the structure. I have endeavoured by careful study of what has previously been written on the subject, to find an explanation of the structure as it is now seen to exist in these specimens, but I have failed in finding any one satisfactory to my mind. For instance, I can find nothing in the structure of Cone-in-cone to warrant the assumption that it was produced by pressure acting on concretions, or from pressure acting on the stratum in any other shape; nor that it is the result of any chemical precipitation from the waters in which it was formed, nor of a concretionary or other form of crystallization in the stratum after the bed was deposited. My specimens show external characters and points of structure which apparently go against all these suppositions, and although the explanation I intend to offer is one that is satisfactory to my own mind and seems to meet all the requirements of the case, I do not assert that it is the only explanation that might be suggested, for I may have overlooked, or may not have properly understood, some of the agencies which conduced to the formation of the structure.[1]

[1] During the progress of my investigations I have had the opportunity of submitting my specimens and sections of Cone-in-cone to Dr. Young, Honorary Member, Professor of Natural History and Geology; to Mr. Ferguson, Professor of Chemistry; to our President, Sir William Thomson, Professor of Natural Philosophy; and to his brother, Dr. James Thomson, Professor of Engineering (in the University of Glasgow), the latter of

Cone-in-cone, as it appears to me, is the result of a mechanical action, set up by chemical agencies, in the stratum in which it is found, and whilst the deposition of the sediment was going on, as I hope to point out more fully later on. It is also a structure, so far as I have seen, that does not affect in the least either the immediately underlying or overlying stratum, and is confined vertically to the thin bed in which it exists, but it may, and does, extend horizontally with the bed over wide tracts of country, as I have already pointed out.

The chemical agencies which seem to have set up the mechanical action in the stratum appear to me, after a careful examination of all the phenomena presented by Cone-in-cone, to have been the outward and upward escape of gases generated probably by the decomposition of organic matter in the deposit. These gases, as they slowly escaped upwards through the oozy and plastic mud, elevated the sediment around the several points of eruption into conical, ring-like layers, the last feeble ebullitions being indicated at the upper extremities or bases of the cones by the little conical eminences, already referred to, which now rise above the regular surface of the bed. With the cessation of the escape of the gases from the underlying sediment the structure ceased to be further extended, although deposition of sediment, apparently of the same mineral composition, still went on in the waters in which the stratum was forming.

It may here be of interest to indicate the nature of the evidence which seems to me to show that the cones were formed while the sediment was still in a highly plastic state. I have already stated that the structure generally commences at a short distance above the base of the stratum with a numerous group of very small cones, each of which in transparent section is seen to have an independent tube or axis of eruption through which was elevated the sediment in inclined layers to the then existing

whom has given much attention to structures in various rock substances, and I am glad to be able to state that so far as my specimens are concerned they are all inclined to agree with me in considering that neither crystallization, pressure, nor chemical precipitation, had anything to do with the formation of the cones, and that to their minds the explanation I have given of the several points of structure being due to the upward escape of gases through the sediment, appears the most probable one, and fully explains the appearances of the various specimens.

surface of the bed. As the stratum increased in thickness, many of these small first-formed cones also increased in size, but the greater number became extinct, and were buried gradually under the higher and more extended layers of the more powerful cones that continued in action to nearly the close, when the structure ended, as we now see, in a group of small but feebly developed cones.

I have pointed out, as characteristic of Cone-in-cone structure in my specimens, the existence of a thin layer of argillaceous mud, apparently unnoticed by previous observers. This separates the calcareous layers, and appears to have been deposited on the inside surface of the cones during the period between one ebullition of gas and another. That these ebullitions occurred at varying periodic intervals seems to be clearly indicated by the varying thickness of the films of clay and layers of calcareous sediment which build up the cone structure. But there is another important character connected with this layer of clay to which I wish to refer, as it bears strongly on the question of the successive formation of the calcareous layers of the cones while the stratum was being deposited. When these dark lines of clay are carefully examined in transparent and vertical sections of the rock they present on their lower surfaces a corrugated or serrated structure, corresponding exactly to the transverse wrinkles or corrugations which, as I have already stated, are to be found on the inner surfaces of all the cones.

If we further examine these black lines of clay, we see that their upper surfaces are never corrugated or wrinkled in any degree, and that they always present an even or comparatively smooth face or slope upon which the next calcareous layer rests. This important character points strongly to the conclusion that the transverse wrinkles seen on the surface layers of the cones were produced by a creeping downwards through gravitation of each of the successive calcareous layers whilst still in a semi-plastic state, and while thus moving downwards the surface film, which had then begun to harden, was dragged into a series of minute corrugations, the number and depth of which are frequently seen to correspond with the size of the cones and the plasticity and thickness of the layers. Similar corrugations to those seen in Cone-in-cone may be often observed where a thin layer of tar, pitch, or thick oil paint has been spread upon a sloping surface.

The outer film in such substances hardens more quickly than the inner portion, and as the layer creeps slowly down the inclined plane through gravitation, the hardening surface is dragged into a series of corrugations, they being, like those of Cone-in-cone, always at right angles to the slope along which the substance was moving. Had this wrinkling of the surface of the cones been produced by any other known agency at some after period of time, we should naturally have expected that the dividing black lines of clay would also have been corrugated, but this is clearly seen not to be the case. In my view the formation of the cone structure seems to have gone on in something like the following manner. In each successive ebullition of the gases which elevated the plastic sediment around the axis of the several cones there were pauses, of longer or shorter duration, the cones meanwhile remaining open at their bases or at the points where their ascending layers terminated at the then existing surface of the deposit. It was during these intervals that the corrugation of the upper or inner surface of each calcareous layer seems to have taken place, and on which the separating film of clay was afterwards deposited from the waters in which the stratum was formed.

The transparent sections which I have prepared clearly show, I think, that the argillaceous mud settled down in each case upon an already corrugated surface, the lower face of the film of clay thus entering in and filling up all the wrinkles, and forming a counterpart or cast of the corrugations, while its upper or inner face afterwards came to present a smooth, even slope, on which the next ebullition or layer of calcareous sediment was deposited. We have thus in our Cone-in-cone structure an alternating series of calcareous and argillaceous layers, each calcareous layer resting upon a smooth face of clay, while the clay layers in their turn rest upon the corrugated surfaces of the calcareous layers. When the calcareous layers are examined in transparent section, under a low power of the microscope, it is seen that the calcite has arranged itself in fine lines, having a semi-crystalline structure, running nearly parallel with the angles of the cones. These lines are crossed at acute angles by other equally fine lines or fissures, and the junction of the two gives a peculiar chevron-shaped or zig-zag structure to the layers, probably due to some crystalline action set up in the calcareous sediment after deposition, but it evidently had nothing to do with its arrangement within the

cones. Many of the sections also show under the microscope that the thin layers of separating clay, ere they had properly consolidated, had been broken up into small pieces and granular fragments, which had been moved from their places by the eruption of the succeeding calcareous layer. We also find these broken-up lines of clay existing between others that are still intact, which shows, I think, that there was some variation in the force or action, and in the period of time between the formation of each layer. I also find in some sections, especially in one from a pit near Paisley, the curious feature that they have their fine lines of calcite dragged or bent backwards into the cone from the weight of clay in some of the layers pressing down the crowns of the corrugations in the calcareous layers, and that seemingly ere they had been properly consolidated—another strong proof, I think, that these layers were in a plastic state when erupted.

I cannot call to remembrance any known form of crystallization, chemical action, or pressure, forming such a structure as that here described, but I think its formation by the method I have attempted to explain is a probable one, and does not go beyond the possibilities of the case. There are other facts which point to the calcareous layers having been elevated by a force acting from below, one being the occurrence, in some specimens of Cone-in-cone, of small fish coprolites which are sometimes seen to plug up the orifice in the central axis of the cones, and to distort and otherwise interfere with their formation; whilst in others, fragments of shells of *Anthracosia* have been elevated so as to coincide with the angles of the layers of the cones. It may be of interest also to note that where shells or coprolites exist in the bed, the Cone-in-cone structure does not exist in these fossils, as might be naturally expected would not be the case under the method of deposition I have pointed out, for they being hard bodies when the calcareous layers were being elevated, the upward tendency of the several ebullitions would be to heave them to the surface of the bed as ejectamenta. It is also seen in many specimens that the bases of the cones, as they reach the surface of the bed, and where the pressure of sediment on the gases would naturally be less, expand somewhat suddenly, the cones thus becoming trumpet-mouthed in shape and the reflexed layers folding over and spreading so as to touch or unite with those of other cones.

When a vertical transparent section is made so as to cut

through the central axis of any of the cones, there is always seen a narrow dark column of clay somewhat less than a line in breadth, extending upwards through the whole length of each cone, and into this column converge all the lines of clay which separate the calcareous layers. The latter, thus, do not touch one another at their extreme apices, and it appears to my mind as highly probable that this orifice or tube from below, through which each succeeding calcareous layer was ejected upwards, was kept open on the line of this central axis during the formation of each cone. There is also another interesting character revealed in transparent sections, showing how the layers of clay were deposited. On examination of these sections, it is seen that during the formation of the deposit there were often interspaces between the bases of the cones as they then existed, and that upon those flattened interspaces, consisting of small heights and hollows, the layers of clay not only rested thicker than upon the inner slopes of the cones, but were often continuous with them. In the sections this character is seen to become more conspicuous as it reaches the upper surface of the bed, for there the cones are often less numerous, and the interspaces between their bases broader than in the earlier stages of the deposit. This clay apparently does not differ either in colour or texture from that which continued to be deposited in the immediately overlying bed, and in which, as formerly stated, Cone-in-cone structure does not exist.

There is one other character revealed in the specimens from Waterland to which I wish to direct attention, as indicating clearly, I think, the formation of the cones while the stratum was still in a soft, plastic condition. It will be seen from some of these specimens that the structure is only very feebly developed, or is sometimes entirely absent, in those portions of the stratum where the bed becomes thin, indicating, as it were, that it required a certain thickness of sediment to be sufficient to generate gases powerful enough to elevate it into distinct conical layers. The upper surface of the stratum, in these thinner portions, is generally smooth, or presents a slightly blistered appearance. In such slabs we sometimes have the curious phenomenon presented of a few widely and irregularly scattered cones of varying sizes, appearing on the surface at intervals, and which in other examples form a united chain of cones extending across the face of the

Illustrations of Cone-in-cone structure.

NOTE.—At the time when these notes on Cone-in-cone structure were written, I was not then certain whether I might be able to get any illustrations of the structure prepared to accompany the paper, hence there has been no reference in the text to figures or plates. I was anxious, if these were given, that they should be produced by some process that would faithfully represent only what the specimens themselves displayed. I have, therefore, been fortunate in getting my friend Mr. Thomas Annan interested in the matter, and he has kindly taken the photographs of several specimens, some of which are reproduced in the two following plates by his new photogravure process; and I here take the opportunity of thanking him for the care and time he has bestowed upon them. I am only sorry that I have not been able to get more illustrations done, as it would require more than is given in the plates to illustrate all the characters of interest that I have noted in the paper.

EXPLANATION OF PLATE I.

FIG. 1 illustrates, slightly reduced in size, the upper surface of a specimen on which the cones are seen to increase in diameter from the left to the right hand side, or to that side in which the stratum is thickest. It also shows the raised and ring-like bases of the cones at the point where they terminated on the surface of the bed, as more fully explained on pp. 10, 11, 16, and 17 of the paper.

FIG. 2 illustrates, natural size, the upper surface of another specimen, in which the raised terminal layers of the cones have fallen out from the surface of the stone through the effects of weathering on the shale heap (pp. 10, 11). These openings also show, at their base, in all the cones, the central axis or tube through which the sediment was erupted, several of these being visible in the illustration (pp. 12, 15, and 16). This illustration further shows the ring-like structure of the cones, and how their forms are interfered with in those portions of the bed where they are crowded together (p. 18).

EXPLANATION OF PLATE II.

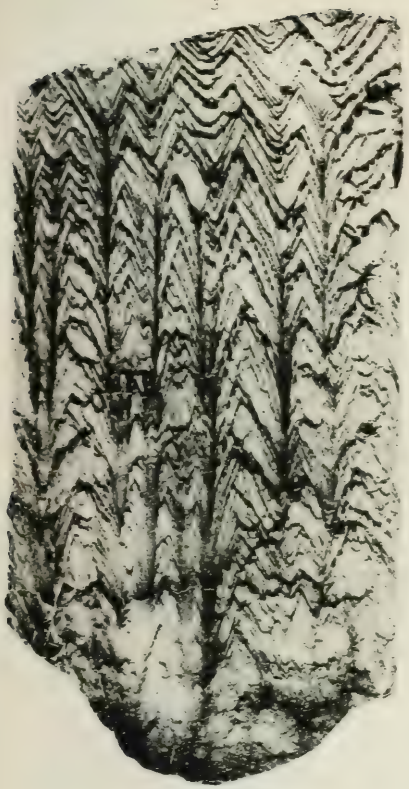
Fig. 3 illustrates, enlarged one diameter, a transparent vertical section of the cone structure. In this section the central axes or tubes of several of the larger cones are exposed throughout a portion of their length. They appear as vertical dark lines in the section, into which converge the dark lines of clay that separate the lighter coloured calcite layers of the cones. The section also illustrates the arched structure that exists between the cones, by the junction of their successive ascending layers (pp. 9, 10, 15, and 16).

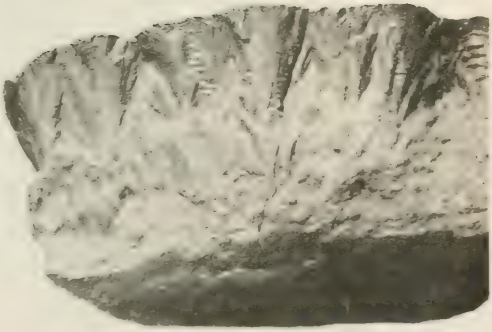
Fig. 4 illustrates, enlarged one diameter, another transparent vertical section of the cone structure, in which is exposed a portion of the lower part of the axis of a powerful cone; from this spring the axes of several independent cones, which, before the specimen was cut, formed a cluster of small cones at the surface of the bed that surrounded the main or central axis (pp. 10 and 24). This section, and that of fig. 3, also illustrate, in many of the dark clay lines, the notched and serrated character of their lower edges, this being due to the transverse wrinkling of the inner upper surface of the calcite layers upon which the lines of clay were subsequently deposited (pp. 13-15).

Fig. 5 illustrates, natural size, a vertical section, showing how the bases or broad ends of the cones expand as they reach the surface of the bed, owing to the gradually lessening pressure of the sediment upon the gases in their escape upwards (pp. 15 and 24).

Fig. 6 illustrates, natural size, a vertical section of a thin portion of the cone stratum, in which the cones are seen to be very numerous and small in the lower portion of the bed, and also shows that only a limited number of these ever reached the surface (pp. 12, 13). This specimen, and that of fig. 5, illustrate on portions of the surface of their cones the transverse wrinkling noted in pp. 13-15.

N.B.—The specimens used for the illustrations were obtained from the quarry at Waterland.





Illustrations of Cone-in-cone structure

specimen like a miniature range of low hills. These cones rise from one eighth to one quarter of an inch above the general surface of the bed, and show in a very distinct manner how the various ring-like layers of sediment were piled up, one layer within another, by the action of the escape from below of the gases at these several points.

If I am right in my conjectures as to the agencies which produced the Cone-in-cone structure, then its cessation in any particular bed might be brought about by the sediment ceasing to give off the gases generated by the decay of the organic matter in the deposit, and this would probably be hastened by the disappearance from the waters of the organisms to which the generation of the gases were due. In the case of the Cone-in-cone from Waterland, to which I have so often referred, it is seen that the Entomostraca so abundantly present in the bed, as also the fishes, ceased in a great measure to exist in the waters of the locality whilst the overlying strata were being deposited, and we have as yet no evidence of the recurrence of several of the Entomostraca in any higher strata.

In most of the other Cone-in-cone specimens obtained from the Scottish coalfields, I have also been able so far to connect the structure with the presence of organic matter in the deposits, and to some of these specimens I will now shortly refer. They are all contained in the Hunterian Museum collection, and have either been collected by myself or given by donors. First is a specimen polished on one face and representing two layers, the lower a musselband, full of the shells of *Anthracosia*, on which rests the Cone-in-cone layer $5\frac{1}{2}$ inches in depth. Both layers are highly calcareous and of a light grey colour. The cones are well developed, and some of those that reach the surface of the bed measure $1\frac{1}{4}$ inches in diameter at their base. In this specimen the cone structure is confined exclusively to the upper layer, the apices of the cones resting on the shell-layer, but not passing downwards into it. There is no locality attached to this specimen, but it seems to be identical in colour and composition with another specimen in the Museum, from Auldton Colliery, near Larkhall, Lanarkshire, the working being in the upper coal measures. In this the cone structure is also $5\frac{1}{2}$ inches in height, but the musselband layer at the bottom is absent or broken away. In both of these specimens the transverse corrugations on the surface layers of the cones are

beautifully marked, the film of clay separating the calcareous layers being of a bluish-grey colour in newly fractured examples. In the polished specimen, it is seen that this clay fills up the corrugations exactly after the manner of those already described from the bed at Waterland. I think it is clearly evident that the Cone-in-cone structure has here been formed through the action of the gases generated by the decomposition of the *Anthracosia* in the lower portion of the stratum. In another specimen from the Airdrie coalfield, in which the cone structure is incumbent on a stratum of blackband ironstone, we find that the organisms which generated the gases were chiefly those of plant remains and fishes. The cone structure is here $7\frac{1}{2}$ inches in height, the stratum being only very slightly calcareous, and of a black colour, while the texture is somewhat coarse; hence, the transverse corrugations on the surface layers of the cones are not so distinctly marked as in those composed of the finer-grained calcareous sediments. The layers of the cones are, however, separated by the usual film of clay, and as the cones ascend to the surface of the bed, these layers, in the several cones throughout the $7\frac{1}{2}$ inches in height, are seen to continually impinge upon one another, only those in the upper portion ever reaching the surface of the bed.

In another specimen, presented by Mr. Robert Craig, from Davies Hill, Dalry, and from the same geological horizon as those from Waterland, we find the Cone-in cone structure 7 inches in height, the individual cones being few, and very large, some even, where their bases reach the surface of the bed, measuring $2\frac{1}{2}$ inches in diameter. Owing to the large size of the cones, the several calcareous and thin argillaceous layers which build up their structure are very clearly displayed, as well as the varying thickness of the calcareous layers, due, I think, to the varying power in the ebullition of the gases by which the sediment forming the layers was erupted. It is interesting to note in this specimen how these layers had their edges truncated or interfered with on one or more sides of the cone, by coming in contact with the opposing layers of more powerful cones, by which they are often overlapped and buried. It also illustrates in a clear manner the structure of the thin layers of clay which separate the calcareous layers, the distinction between the two being brought out more strongly on its weathered face, where the calcareous layers have been bleached from a dark, blackish-grey into a light, yellowish-

grey, the lines of separating clay being unchanged, and of a deep black colour. These thin layers of clay are of varying thickness, but when viewed in section they all show, in a very beautiful manner, the serrated character of their under edges, these serrations, as formerly stated, being the counterpart of the transverse corrugations seen on the inner upper surface of the several calcareous layers of the cones, the wrinklings of each layer taking place while it was in a soft and plastic state, and the thin film of black mud being subsequently deposited from the water upon the corrugations of the cones.

In another specimen from Hunter's Hill Pit, Bishopbriggs, north of Glasgow, and on the same geological horizon as that last noticed, but distant at least twenty miles in a straight line from it, we have a Cone-in-cone structure developed in flat, nodular-shaped masses in a clay carbonate of iron. The cones are about three inches in length, and as their bases reach the surface of the bed they suddenly expand, their layers folding outwards so as to give the cones a kind of bell shape. These cones are well formed, and have the usual corrugated surface, with films of clay separating the layers. In another pit near the Barracks, Maryhill, and about three miles westwards from Bishopbriggs, we find the same Cone-in-cone stratum existing. Here also it occurs in flattened, nodular-shaped masses, in an impure and very coarse kind of clay-ironstone. The cone structure is rarely visible on their external surfaces, but when broken up they show all the usual characters, viz., the corrugated layers and the separating lines of black clay, though in a very imperfect and ill-formed condition. It appears to me that the less perfect development of the cone structure in this locality is chiefly due to the coarser sediment in which the structure has been formed, it being composed of a black, arenaceous and ferruginous mud, in which very little calcareous matter exists. The cone structure is further obscured by the twisting and crushing of its layers through vertical pressure, after the cones were formed, many of them being completely squeezed into a mass of confusion, instead of standing erect in the bed. The only organisms I have noticed in connection with the structure at this locality are fragments of plant remains and coprolites of fishes ; but they seem to be rare, and this scarcity of decaying organic matter in the stratum whilst it was in the process of formation, may, through the feebler

ebullitions of the gases generated, have prevented a more perfect development of the cone structure.

I have to notice also two other specimens of Cone-in-cone from our upper coal-measures in connection with organic remains—one from a pit put down some years ago near Provanhall, a few miles east of Glasgow, and the other, recently presented by Mr. John Kirsop, from the Gilbertfield pit, also east of Glasgow. Both of these specimens formed portions of large flattened, nodular-shaped masses, and both probably from the same horizon of strata. The former has the cone structure 4 inches in height, some of the cones at their bases measuring nearly 3 inches in diameter. The cones are finely formed, the transverse corrugations on the surface of the layers being large and deeply marked, whilst the colour of the cones is of a deep shining black, due to the dark carbonaceous clay by which their surface is coated. A few shells of *Anthracosia* are also to be seen in the lower portion of the stratum. In the specimen from Gilbertfield the larger cones are 2 inches in height, but in one portion the formation of the cone structure is somewhat interfered with by the *Anthracosia* shells present. I have already stated that where large shells or fish coprolites are present that they always show interference with the formation of the cones, the structure in transparent sections apparently not passing through these organisms, as I think it would have done, had it been due to either crystallization or pressure at some subsequent period. Mr. Thomas Naismith has also recently presented me with some very fine examples of Cone-in-cone from the same horizon of the upper coal-measures to the east of Glasgow. The point they illustrate is the connection of the structure with the shells of *Anthracosia*, whilst the specimens also show in a very beautiful manner the corrugated surface of the cones, and the way in which the more powerful and later-formed cones have interfered in their layers one with another in their upward growth to the surface of the bed.

The only other example of Cone-in-cone that I have been able to examine, except those already noticed from the Western coal field, is a specimen from the Lias formation of Whitby, presented by Mr. D. C. Glen, F.G.S. In this example the cone structure measures $3\frac{1}{2}$ inches in height, and is well developed, the cones expanding rapidly and some of them at their bases measuring $2\frac{1}{2}$ inches in diameter. The rock is of a dark grey colour, and is

composed of two distinct series of layers, viz., layers that are strongly calcareous, and layers that are argillaceous, and not affected perceptibly by acids. In the specimen under notice, the transverse corrugations are well marked, being large on the larger cones and small on the smaller; and it is clearly seen that they are, like those previously noticed from our Carboniferous strata, confined to the inner face of the calcareous layers of the cones. The clay that separates the calcareous layers is of a darker colour than they are, and glistens with minute scales of mica; and also shows in sections of its lower surface similar serrations to those seen in the Carboniferous specimens. I do not know the conditions under which this Cone-in-cone bed exists in the Whitby Lias, but as far as my specimen shows there is no trace of organisms in connection with its cone structure, though they may exist in the underlying stratum, as is seen to be the case with most of those from Scottish Carboniferous strata. It has evidently been broken from a shore bed which has had its upper surface abraded by the action of the waves; but this surface shows clearly that the cone structure terminated in the stratum with a group of smaller cones similar to those seen in the specimens from Waterland previously noticed, and I am further pleased to observe in it that all the characters agree in every detail with those from our Carboniferous strata.

In bringing these remarks to a close, I have only further to observe shortly that I do not know of any instance of Cone-in-cone structure being found in connection with undoubted marine deposits in Scotland, such as the limestone strata. I do not assert that such does not exist, but so far as the evidence goes the organisms found in connection with the Scottish specimens indicate freshwater conditions for the beds, and, from the extent of country over which these are known to extend, lacustrine rather than estuarine conditions of deposit.[1] I have already stated

[1] Recently our member, Mr. James Bennie, of the Geological Survey of Scotland, kindly sent me two specimens from a band of Cone-in-cone from 4 to 6 inches in thickness, which occurs in connection with a bed of soft earthy shale some 7 feet in thickness, at a point on the Fife coast near St. Andrews, known as the "Witch Lake." Mr. Bennie states that throughout this shale bed on which the cone stratum rests there occur marine organisms, but not in very good preservation. The cone stratum exists as two layers, being parted by a seam of fine encrinal debris, varying from 1 to 2 inches in thickness, but into which the cone structure does not extend from either of the layers. This encrinal debris has all the appearance of

that Cone-in-cone structure is not everywhere well developed or indeed even always present over the whole area in which the stratum is found. The presence or absence of development may perhaps be difficult of explanation, being possibly due to one or more of several causes, such as depth and temperature of the waters in which the structure was formed, and to differences in the composition of the sediments at various parts of the area of the old lake bottoms. These variations of conditions may also probably have acted upon the distribution of the organic life in the deeper and shallower tracts of water, and may also have acted in some instances in hastening or preventing decomposition of the organic sediment, and thus altering the action of those gases to which I think the origin of the structure was undoubtedly due. Another point to which I would like to advert is that while the structure in all the specimens I have examined presents identical characters, yet there are variations between the mineral composition of one stratum and another. Some Cone-in-cone structures are so strongly calcareous that they might be considered impure limestone, while others are more argillaceous and ferruginous, with only a small percentage of lime in their composition.

I have never met with Cone-in-cone structure in Scottish beds showing any tendency towards an oolitic character, neither is it seen in the Lias specimen noticed. I do not, however, assert that oolitic structure may not exist in some varieties of Cone-

having been drifted from a deeper tract of the sea-bottom into shallower water where the cone structure was forming, and although under marine conditions, these seem to have been such as favoured the escape of gases from the decaying organisms in the bed. The argillaceous deposit in which the cone structure exists is of a somewhat coarse texture, the cones therefore not being so finely developed as we find them in finer grained sediments. From what Mr. Bennie points out as to the nature of the strata in which this marine bed is intercalated, I think they are such as strongly favours the assumption that we have here a series of deposits comprising old land surfaces, and freshwater or lacustrine beds alternating with marine ones. The strata are as follows—Sandstone and sandstone shales; grey shales and fireclays, with sandstone containing *Stigmaria;* coal with shale intermixed; marine shale with stratum of Cone-in-cone; ironstone nodules and limestone bands; fireclay, black coaly shale, coal, and sandstone with coal and shale. This interesting section is the first in which I have seen Cone-in-cone associated with undoubted marine remains, although the bed has all the appearance of having been deposited in what may have been a marine swamp.

in-cone, but I cannot accept Dr. Sorby's view that the formation of Cone-in-cone proceeded after the same plan as that which he states he had been able to ascertain, through the crystallization of "some kind of oolitic grains," for I have already shown that the Cone-in-cone structure under notice is composed of two distinct sediments, alternating with each other in the several layers; and further that the cone structure, with all its attendant phenomena, must have been formed ere the crystallization seen in its calcite layers was set up—this crystallization and that seen in oolitic grains having both been effected since the deposition of their strata.

From what I have read regarding some of the so-called Cone-in-cone structures already described by authors, I am much inclined to believe that they are not all genuine Cone-in-cone—for instance, that called the "beef-beds" and that said to be found in some "coals." I think if such were carefully examined that they would be found to differ very much, in their structure, from the Cone-in-cone specimens which I have brought before the Society, and that they were probably formed by different agencies from those I have here noticed.

In concluding, I offer the following as an epitome of the chief points of Cone-in-cone structure as noted in the foregoing pages, and as illustrated by the specimens and sections exhibited. As previously stated, some of these points do not seem to have been formerly noticed or described, and I am therefore anxious that they should be presented to your consideration in as clear and concise a manner as possible. They are as follows:—

1st. That Cone-in-cone structure appears to be due to the upward and successive escape of gases generated in the lower portion of the stratum in which the structure is found, probably by the decay of organic matter in the deposit whilst still in the process of formation and in a soft, sedimentary condition, each ebullition of gas being marked by a new or successive layer of sediment within each cone.

2nd. That Cone structure is seen to be composed of two distinct and alternating series of layers, successively formed within each other as the cones grew upwards; one of these layers being always more or less calcareous and ferruginous, the other layer being argillaceous, and that it is to this difference in the lithological composition of the layers that their ready separation along the vertical lines of junction in the cone structure is due.

3rd. That the cones, large and small, are seen to have their apices invariably directed towards the lower portion of the stratum, and that near the bottom the cones are numerous and small, but as they grow upwards, from successive increasing layers of sediment, their bases keep gradually expanding until the edges of the several layers, in contiguous cones, impinge on each other, forming a series of acutely ascending arches; or, in cases where the action has been more powerful, overlapping and burying the weaker cones, ere they reach the terminal surface of the deposit where the cone structure ceases. At this point the bases of the cones are seen to expand more suddenly, the layers being slightly reflected outwards, so as to give the broad ends of the cones a trumpet-mouthed shape, this expansion being due, I think, to the lessening pressure of the sediment on the ebullitions of gas as they neared the surface of the deposit.

4th. That the transverse corrugations, or wrinklings, seen on the inner upper surface of the calcareous layers of the cones, appear to have been due to a creeping downwards from gravitation of the gradually hardening surface of the layer of sediment, whilst it was still in a plastic state; and that upon these corrugated, calcareous layers there have been successively deposited from the waters in which the stratum was forming those thin argillaceous layers which now separate the calcareous layers in all the specimens.

5th. That transparent vertical sections show the existence in all the cones of a small central axis, into which all the argillaceous layers converge and unite so as to form a dark-coloured tube, filled by the clay, and that through this orifice of the axis the sediment forming the calcareous layers was successively ejected during each ebullition of the gas from below, the action being comparable to that of a miniature geyser.

6th. That the Cone structure terminates in a series of minor cones planted within the bases of the larger ones, and that where the surface has not been abraded they are seen to rise to variable heights above the general level of the deposit, the smaller cones showing clearly that the ebullition of the gases which formed the larger cones was suddenly decreasing, the ejected sediment being small in amount, and only able to form within the base of each cone a variable number of small, ring-like conical eminences, one rising slightly higher within the other; until in the last, which now forms the central cap or ring in the minor cones, being less in

bulk than the head of a small pin, the formation of the Cone structure is brought to a close.

Since this paper was read, I have had specimens of Cone-in-cone sent me from three localities in the English coalfield—one from the neighbourhood of Sheffield, by Mr. G. R. Vine, and two from pits in the South Welsh coalfield, by Mr. R. Kidston, F.G.S. I have also been able to examine various other specimens from the Scottish coalfield, but in none of these have I found characters differing from those I have here described, or the formation of which cannot be accounted for by the theory I have set before you.

I may here also take the opportunity of stating that Professor J. S. Newberry, M.D., has recently contributed a short article on Cone-in-cone to the *Geological Magazine* (December, 1885), in which he notices the abstract report of my paper which appeared in the number of that magazine for June of the same year. He there states that "the theory of the escape of gases through a pasty medium" had likewise occurred to him. He goes on to say that when a student at the Jardin des Plantes, Paris, and attending the geological lectures of M. Cordier, who described Cone-in-cone as an imperfect crystallization, he (Prof. Newberry) "proposed to him the theory of the escape of gases through a pasty medium, but Professor Cordier said that would not do, because the points of the cones were sometimes turned upward, sometimes downward." Professor Newberry next refers to the numerous opportunities he subsequently had of observing Cone-in-cone in various localities, and in many geological horizons, whilst conducting the surveys in several of the American territories. He says —"More generally the Cone-in-cone structure is observable in lenticular sheets of earthy limestone or shale impregnated with lime, and in each sheet the cones are usually turned in the same direction, oftenest with the points down, but sometimes turned upward, and occasionally turned in both directions." After referring to examples in which the cones are seen to be divergent around the surface of nodular masses, he states, in conclusion, that "such specimens as these I have described seem to me to be incompatible with the theory that Cone-in-cone is caused by pressure or the escape of gases, and appear to confirm the conclusion that it is due to an impeded tendency to crystallization."

Remarking on this, I have only to state that neither Professor Newberry nor any of those who have adopted a crystallization theory

for the formation of the cones have offered any explanation as yet of any known law of crystallization which would satisfactorily account for all that is seen in the internal structure and external characters of the best preserved specimens of Scottish Cone-in-cone, such as I have described. If the structure is due to an "impeded crystallization," I would ask those who support this theory, what would have been the ultimate form and internal structure of the cones had the crystallization in the stratum been carried on farther, or to its fullest extent? It is strange that in all the localities and countries of the world where the structure has been observed, the agency by which it was formed has always stopped at a stage corresponding with the complete formation of the cones. If, on the other hand, we view the structure as due to the action of chemical and mechanical agencies, then we see that it is as perfect in all its details as we could expect it to be from the operation of such agencies. Professor Newberry's remarks, however, do not offer any explanation of the structure, being wholly confined to the evidence derived from the direction in which the points or apices of the cones are turned in the bed; and as some of his examples differ much from anything that has come under my observation, they are beyond discussion in the present paper, and will have to be described with reference to their external characters and internal structure.

In all the lenticular and nodular masses of Cone-in-cone from our coalfields that have come under my notice, the cones have only had a very slight inclination from the perpendicular or normal position they usually assume in the bed. Where any radiation is seen it is usually in these lenticular masses. In a level, continuous stratum the cones are always vertical. On thinking over the causes that may have led to this outward bending of the cones, I am inclined to ascribe the arrangement to the contraction inwards and downwards towards a central nucleus of the material forming such masses during the aggregation and solidification of their elements in the sediments in which they are found. In such nodular and lenticular masses as are traversed by septaria, which were originally open contraction-fissures in their interiors, we have a sort of measure as to the amount of surface-contraction that has taken place in nodules without septaria. In the septarian nodules the contraction is seen to have been greatest in the centre and least towards the outer surface, where the con-

traction-fissures are seldom visible, while in many of those without septaria the contraction is often seen to have taken place by a bending inwards of the upper surface of the mass. As the contraction went on there seems to have been a strong pulling inwards and downwards of the still yielding upper surface towards the nucleus where solidification was going on, the convexity becoming greater and the horizontal area diminishing, until complete solidification had taken place. This contraction of the area of upper surface in nodular and lenticular masses is finely illustrated in the large nodules of clay ironstone found in the section of Carboniferous limestone strata exposed on the hillside at Corrieburn, Campsie. In many of these the upper surface and edges are so much curved inwards that they now have a great concavity in their bases. These nodules do not show any Cone-in-cone structure, but they show such evidences of contraction, internally and externally, as naturally lead us to conclude that where similar nodules exist in a Cone-in-cone stratum the tendency must have been to cause the cones formed in their normal vertical position to assume a radiating inclination around the gradually contracting and aggregating mass. Where the contraction would be greatest, as in the more argillaceous nodules, there may have been a bending, and in some instances a complete inversion of the cones around the edges of the nodules.

This explanation may not suit every case in which the Cone-in-cone structure is seen to be different from that which I have described; but holding the view that the cone structure, in any stratum in which both structures are found, preceded the formation of the nodular masses by a period of time corresponding in length to that required for the aggregation and solidification of the nodules, I believe that, so long as these two forces were at work, we might expect to have had that there were movements in the gradually contracting masses. The amount of radiation in the cones around the curved surfaces may possibly afford as clear an index to the amount of contraction which has taken place as do the septarian fissures in the interior of other nodules.—[Jan., 1886.]

No. II.—On the Upper Limestones of North Ayrshire, as found in the District around Dalry, and elsewhere.

By Robert Craig, Langside, Beith, *Cor. Mem.*

[Read *8th January*, 1885.]

Introduction.—The Upper Limestones of North Ayrshire are divided into four distinct series of beds by the intervention of shales and flaggy sandstones, giving to each an independent character, both physically and in extent of area. They are all rich in fossil remains, but, with the exception of the lower bed of the series, they are of small commercial value, and the collector has not therefore the opportunity of searching quarries, as in cases where the limestones are more extensively worked. However, from the openings made by, and the sections exposed in, the various water-courses, a fair collection of their fossils has been obtained, and to all appearance the series are as rich as the Lower Limestone beds, both in quantity and variety of their organic remains. They differ, however, from them in the proportions they contain of the same classes of fossils, as for instance corals and crinoids, in which the Upper beds are poor both in genera and species when compared with the rich deposits of the Lower Limestones. Full lists of the fossils are appended to this paper.

Highfield Limestone.—The first, or lower, bed of the series is a deposit of limestone and calcareous shales known as the Highfield Limestone, from being largely wrought at the place of that name. From a similar reason it is also known in a neighbouring locality as the Swindridge Limestone. It is divided from the Lower Limestone series by about 120 fathoms of strata, which hold the workable coals and ironstones of the Lower Limestones (see *Transactions*, vol. vii., page 86), and lie from 15 to 25 fathoms above the Borestone, or Dalry, main coal. It is of fine texture and is well adapted for iron smelting. Its general thickness is 6 feet, but it is found as thin as 3 feet, seldom rising above the one or falling below the other.

It is found throughout the parish of Dalry, and crosses to the south and south-east of Beith, near Barr. It appears in the Caldwell coalfield, cropping out on the north-east of Lochlibo, near Shelford, Neilston. It crosses into Ardrossan on the south-west, near Girthill, and is seen at the railway station, Ardrossan, nearly on edge and close to the Castlehill. It is found on the south of

the large fault which runs from Ardrossan up the Dusk and Lugton valleys into Renfrewshire. Crossing into Kilwinning parish, it runs south-east by Goldcraig, Lylestone, and Clonbeith into the south of Stewarton parish. In all these places it has been extensively wrought, and is still worked at the latter place. It is found too in the parish of Galston, and is largely wrought at Moscow and also at Cessnock. Some doubts have been expressed as to whether the limestone worked at these places is the continuation of the Highfield bed, the line of outcrop being broken; but, as it is on the same horizon and bears the same physical and fossiliferous character as the Dalry deposit, it may be accepted as the same until it is proved to be different.

This limestone is almost unfossiliferous,—very few fossils of any kind being found in it,—but both below and above it are associated deposits of calcareous shales very rich in fossils. These shales, with the limestone, have a thickness generally of 12 feet, though this is not persistent, rising sometimes above, and in other places falling below it. The following section taken from the Rye and Caaf Waters, Dalry, shows the deposits at their greatest thickness; the limestone with the shales below it are taken from the Caaf, and the shales above the limestone from the Rye.

	Ft.	In.
1. Shale, calcareous,	2	7
2. Limestone, band,	0	5
3. Shale, highly calcareous,	3	9
4. Shale, calcareous,	2	3
5. Limestone, Highfield,	4	3
6. Shale, calcareous,	3	10
7. Shale, slightly calcareous,	5	1
8. Limestone, band, coarse,	0	10
	23	0

The fossils are more abundant in the shales which partake of a calcareous character than in those which are less so.

The more abundant organisms are—*Productus latissimus*, J. de C. Sow.; *Nucula gibbosa*, Flem.; *Leda attenuata*, Flem.; *Euomphalus carbonarius*, Sow.; *Bucania* (*Bellerophon*) *Urei*, Flem. Of the other shell remains, which are given in full in my list at the end of this paper, one genus or species may be very abundant in one locality and very rare in another, as for instance at Swindridge, Dalry, where *Aclisina* (*Murchisonia*) *striatula*, De Kon., is

very abundant, while at Girthill, Ardrossan, it is rare, and *Pleurotomaria monilifera*, Phill., is abundant. With this variation in distribution the same classes of shells are found throughout the whole extent of the deposits. Crinoid remains are found in the highly calcareous shales of the deposit, while corals, though present, are rather rare. Fish remains, in scales and teeth, have been found at Swindridge, Highfield, and Goldcraig, though they do not appear to be very common. Still, I believe, from what the small openings in the series have produced, that with the same opportunities of collecting as in the quarries of the Lower Limestone series, an equal abundance of organic life would be found here.

These deposits, which I here place as the lowest of the Upper Limestone series, have a more extended range than any other beds of the series. Although much broken up and full of wants, they are found in their detached basins nearly co-extensive with the Lower Limestone series in North Ayrshire; their line of outcrop being found within that series, but running generally in a parallel line to it.

Hundred Fathom Limestone.—In the pits which lie to the west and south-west of the village of Dalry there is found a coarse limestone, with associated shales, which the pit sinkers call by the above name, from a belief that it lies 100 fathoms above the workable clayband ironstone. It is of no commercial value, and to the palæontologist, as a field for collecting fossils, it is useless. The only surface section with which I am acquainted is one in the Braidly Burn, Dalry, close to a pit that lies to the north of the Cemetery, where it is thrown up by a fault, or break, in the strata, and the following section, taken in ascending order, is exposed :—

	Ft.	In
1. Limestone, fossiliferous, ...	—	7
2. Shale, unfossiliferous, ...	2	6
3. Limestone, fossiliferous, ...	4	3
4. Shale, part fossiliferous, ...	6	6
	13	10

The few fossils that can be picked up are, from atmospheric influences, useless for the cabinet, but not destroyed beyond identification. The limestones and the lower half of the higher shale

hold the following shell remains:—*Athyris ambigua*, Sow.; *Orthis resupinata*, Mart.; a few species of *Productus*, and *Spirifera trigonalis*, Mart.; but all very fragmentary and fragile. Indeed, but for making my paper as exact as possible in giving the calcareous beds of the upper series, it was scarcely worth while to include this deposit as one of the Upper Limestones. It appears to be of very limited extent, and is wholly confined to a small area around Dalry. It lies 11 fathoms above the Highfield Limestone.

Lower Linn Limestone.—Between the Hundred Fathom Limestone and that known as the Lower Linn Limestone lie about 24 fathoms of flaggy sandstones and arenaceous and clay shales, holding a few badly-preserved plant remains, but otherwise of no value. Resting upon these strata is the Lower Linn Limestone, which, in its greatest thickness, with its associated shales, is 36 feet. This measurement is taken from the pits on the Linn and at Langlands; but good sections of the shale, below the limestone, the latter being reduced in thickness, are to be seen on the Caaf Water both above the bridge near Linn and farther down the stream.

The shale here, lying below the limestone, and which has a thickness of about 6 feet, rests upon a thin seam of coal, and is very fossiliferous; but the fossils are very fragile from exposure to the weather, and few cabinet specimens are found. The most abundant are *Athyris ambigua*, Sow.; *Orthis resupinata*, Mart.; *Productus latissimus*, J. de C. Sow.; *P. longispinus*, Sow., var.; *P. semireticulatus*, Mart. Fragments of *Phillipsia Eichwaldia*, Fisch., are found, but appear to be rare.

Sections of this shale, holding the same fossils, are found in the Rye Water. Resting upon it lies the Lower Linn Limestone, reduced to 13 feet in thickness, and consisting of a series of thin-bedded limestones, being little better than indurated calcareous shales, full of nodules of carbonate of lime, the beds running from 6 inches to 18 inches in thickness. Being of no commercial value, they are not worked, and hence there is no good opportunity of testing their fossiliferous character. In the sections exposed in the Caaf and Rye Waters, Dalry, organic remains are rare; while in those in Monkcastle Glen and Lugton Water, Kilwinning, and on the sea-shore at Saltcoats, they are entirely absent. In the section on the Caaf a few fossils are found in the nodules of purer limestone, which are got by breaking up those pieces that have

become disintegrated and have fallen into the water. It is worthy of notice that a specimen of a large variety of *Spirifera trigonalis*, Mart., which I presented to the late Dr. Thomas Davidson, was found in one of these nodules. Other specimens of the same fossil, of good size, have been found, but all of the common type. These, with a few fragments of *Productus*, a few badly-preserved specimens of *Aviculopecten*, and a fragment of a Trilobite, are all that have come under my notice.

Upper Linn Limestone.—At Linn, and in the pits around it, 8 fathoms of shales and flaggy sandstones divide the Lower and Upper Linn Limestones. In other localities, and even 1 mile east of Linn, the shales are much thinner, while at Saltcoats they are absent and their place is filled up by about 40 feet of volcanic rocks. This deposit is of similar character physically to that of the Lower Linn beds. It consists of a series of thin bedded limestones of no commercial importance. The nodules, which are of a purer carbonate of lime, make up nearly one half of the beds, and are sometimes burned by the farmers on whose ground the beds crop out, as at Bourtrapping, Dalry. They make a fair lime for farming purposes; elsewhere they are only worked for road metal.

The following is a section as found at Linn Spout, Dalry, from which these beds take their name, but taken upwards:—

	Ft.	In.
1. Coal, from 2 feet to	5	0
2. Shale, indurated, ...	1	3
3. Limestone, ...	1	2
4. Shale (full of shells of *Estheria punctatella ?*), .	0	8
5. Limestone, ...	1	0
6. Shale, very fossiliferous, ...	5	9
7. Limestone, Upper Linn, ...	35	0
	49	10

These Upper Limestones, with the exception of the Highfield or Lower beds, have a limited extension, being mostly confined to a small area around Dalry. They also extend into the north of Kilwinning parish, and are found in the same parish on the Lugton Water much reduced in thickness. I was informed by the late Mr. Danks, mineral borer, that he had bored through them in the south of Stewarton parish where they had a thickness of 30 feet, but I question the correctness of this information.

Two beds of limestone are found interbedded among the volcanic rocks on the shore at Saltcoats, and these may be the Linn limestones, though it is doubtful. However, they are on the same horizon, and as the section on Lugton Water is contiguous to the volcanic rocks there, these beds may be an extension of the Linn limestones, as the beds of limestone between Ardrossan and Saltcoats, which the Survey put down as uncertain Linn, are the beds of the Lower Limestone series thrown up by a large fault.

The section exposed at Saltcoats, in the harbour, and north of the old Salt Pans, is as follows :—Coal, about five feet; volcanic, "white horse," $2\frac{1}{2}$ feet; volcanic, variety of melaphyre, about 30 feet; limestone, 6 feet; volcanic tuffs, etc., about 40 feet; limestone, 12 feet; volcanic tuffs, dolerites, etc., about 50 feet; and above these lie the Upper Coal measures of this part of Ayrshire. The two beds of limestone, which are much altered by their contact with the volcanic rocks, appear to be unfossiliferous, but otherwise they are of similar character to the beds at Linn Spout. If they are not a continuation of those beds the Linn limestones have no place on the Ardrossan and Saltcoats shore.

Returning to the sections opened at Linn Spout, Glencart, Dalry, and Monkcastle Glen, Kilwinning, where the upper beds are well exposed, being worked in the two former places, they are found to be of the same physical character as the Lower Linn beds, but are richer in organic remains. From their nodular character, these limestones disintegrate very rapidly, and in the glen at Linn Spout from this cause they have a broken and shivery appearance.

The men in charge of the pits around Dalry hold an opinion that the shales between the upper and lower Linn series of beds run off, and that the two run into one bed, as two beds of coal sometimes do. This idea, however, is unworthy of notice, but I refer to it as the officers of the Geological Survey have adopted it, in paragraph 28 of the Explanation to sheet 22 of the Ayrshire Survey. It is quite true that to the east of Dalry the lower series of beds run off, only one bed being found, but this is the upper series of beds alone, as may be seen from the following fact. In the Linn and Langland pits, and at Linn Spout, on the bottom of the upper series, is a band of hard sandstone full of shell remains. At Bourtrapping and at East Bankend, where only a part of one bed is on, it is still found attached to the bottom of the beds. Now, if the two series of beds had run together, this band would have

been found at the junction of the beds, just resting upon the top of the lower bed ; but this is not the case. I think therefore that there is sufficient proof that the two series do not run together as the Survey officers suppose.

As already mentioned, the upper series of beds, wherever exposed in the neighbourhood of Dalry, are rich in fossils, but, as in the Lower Linn beds, they are mostly confined to the nodules of purer limestone, few being found apart from them. At Linn the nodules are very hard, and the shell remains are much crushed ; at Bourtrapping they are not so much crushed, and good cabinet specimens are more easily procured.

The more common fossils, both at Linn Spout and Bourtrapping, are as follows. Corals, and broken stems and arms of Crinoids are found, though not abundantly, and in some of the beds appear to be absent. Polyzoa are got in some of the beds, though not well preserved. In a few feet of the beds, on a horizon about 6 feet from the bottom, remains of the Trilobite, *Phillipsia Eichwaldia*, Fischer, are abundant ; but in the other part of the beds they are all but absent. The Brachiopoda are abundant, the more plentiful being *Athyris ambigua*, Sow., *Orthis resupinata*, Mart. ; *Productus cora*, D'Orbigny ; *P. longispinus*, Sow.; with the variety *lobatus*, Sow. ; *P. latissimus*, J. de C. Sow., *P. punctatus*, Mart. ; *P. scabriculus*, Mart. ; *P. semireticulatus*, Mart., and the variety *P. concinus*, Sow. ; *Rhynchonella pugnus*, Mart. ; *Rhyncopora Youngii*, Dav. (this little shell is rather rare, and is generally found in small nests both at Linn Spout and Bourtrapping) ; *Spirifera trigonalis*, Mart. ; *Martinia glabra*, Mart. ; *M. Urei*, Flem. ; *Reticularia lineata*, Mart. ; *Dielasma hastata*, Sow., with its varieties, *sacculus*, Mart., and *vesicularis*, de Kon. ; *Streptorhynchus crenistria*, Phill. The Lamellibranchs are rather rare in the beds, but a specimen is occasionally met with, as *Aviculopecten interstitialis*, Phill. ; *A. orbicularis*, M'Coy ; *Nucula gibbosa*, Flem.; besides a few others given in the list appended to this paper.

Few Gasteropods are found by hammering in these beds, although by careful manipulation some may be got. The greater number named in the following list were found by washing the *debris* obtained in cavities in the limestone formed by the dissolution of the purer carbonate of lime in the nodules through the infiltration of water containing carbonic acid. The Cephalopods are also badly represented. In a bed near the top of the series, at

Linn Spout, a number of *Orthoceras* are found, but too sorely crushed for certain identification, and in the hard sandstone band at the bottom of the series, *Nautilus nodiferus*, Armst., is found, as well as a few fragments of others. Fish remains have also been got, as the teeth of *Petalodus Hastingsiæ*, Owen; *Tomodus convexus*, Ag.; a few fragments of *Helodus didymus*, Ag., and one specimen of *Helodus planus*, Ag. They all appear to be rare, but the probability is that, with the opportunities afforded by more extensive working, these Upper Limestone series of beds would yield to the collector as rich a harvest of fish remains as the beds of the Lower Limestone series have done.

In conclusion, I have once more the greatest pleasure in thanking my friend Mr. John Young, F.G.S., of the Hunterian Museum, Glasgow, for the kind assistance he has afforded me in the identification of fossils, and in the correction of the nomenclature—a kindness of which I have experienced the benefit for now a quarter of a century. Without the help of his extensive palæontological knowledge, the lists of fossils appended to this and to previous papers of mine on the Carboniferous strata of the Beith and Dalry districts could not have had the scientific value which I hope they possess; and I therefore take this opportunity of acknowledging the help I have received from him, and which has alway been given with a readiness as hearty as it is valuable.

For the list of fossils see the following page.

LIST OF FOSSILS IN THE UPPER LIMESTONES OF NORTH AYRSHIRE.

	Highfield Limestone.			Lower Linn Limestone and Shale.	Shale below Upper Linn Limestone.	Upper Linn Limestone.		
	Swindridge.	Goldcraig.	Girthill.			Bourtrapping.	Glencart.	Linn Spout.
Actinozoa.								
Chætetes (*Alveolites*) *septosa*, Flem.								x
Cyclophyllum fungites, D. and T.						x	x	x
Fistulipora incrustans, Phill.				x				x
Heterotrypa tumida, var. *miliaria*, Nich.	x			x				x
Lonsdalia floriformis, Mart.							x	x
,, *rugosa* (?), M'Coy.						x		x
Zaphrentis patula, Mich.	x	x		x	x			x
Echinodermata.								
Archæocidaris Urei, Flem.	x		x					
Actinocrinus, sp. (?).	x	x						
Poteriocrinus crassus, Miller.	x		x		x			x
Cyathocrinus ellipticus, Phill.			x					
Pisocrinus globularis, de Kon.			x		x			
Annelida.								
Serpulites membranaceus, M'Coy.						x		x
Crustacea (Ostracoda).								
Bairdia plebeia, Jones and Kirby.	x							
Cytherella concinna, J., K., and B.	x							
,, *obliquata*, G. S. Brady.	x							
Leperditia Okeni, Munster.	x							
Kirkbya (*Beyrichia*) *radiata*, J. & K.	x							
,, *Eichwaldiana*, J. and K.	x							
Crustacea (Trilobita).								
Phillipsia Eichwaldi, Fischer.						x	x	x
,, ,, var. *mucronata*, M'Coy.	x							
Crustacea (Phyllopoda).								
Estheria (?) *punctatella*, Jones.					x			
Polyzoa.								
Fenestella tuberculo-carinata, Ether. jun.								x
Glauconome elegans, Y. and Y.								x

	Highfield Limestone.			Lower Linn Limestone and Shale.	Shale below Upper Linn Limestone.	Upper Linn Limestone.		
	Swindridge.	Golderaig.	Girthill.			Bourtrapping.	Glencart.	Linn Spout.
Brachiopoda.								
Athyris ambigua, Sow.	x	x	x	x	x	x	x	
,, *Royssii* (?), Lév.				x	x		x	x
Chonetes Laquessiana, de Kon.	x				x			x
Discina nitida, Phill.								x
Orthis Michelini, Lév.				x	x			
,, *resupinata*, Mart.	x	x	x	x	x	x	x	x
Productus cora, D'Orb.								x
,, *giganteus*, Mart.		x						
,, *longispinus*, Sow. (var.)	x				x	x	x	x
,, *latissimus*, J. de C. Sow.	x	x	x	x	x	x	x	x
,, *mesolobus* (?), Phill.								x
,, *scabriculus*, Mart.		x		x	x	x		x
,, *semireticulatus*, Mart.	x	x		x		x	x	x
,, *sinuatus*, de Kon.						x		x
,, *Youngianus*, Dav.				x				
Rhynchonella pugnus, Phill.	x	x	x		x	x	x	x
Rhynchopora Youngi, Dav.						x		x
Spirifera trigonalis, Mart.	x	x	x	x	x	x	x	x
Martinia (*Spirifera*) *glabra*, Mart.						x		x
,, ,, *Urei*, Flem.					x	x		x
Reticularia (*Spirifera*) *lineata*, Mart.						x	x	x
Streptorhynchus crenistria, Phill.	x	x	x	x	x	x	x	x
,, ,, var. *radialis*, Phill.	x							
,, ,, var. *senilis*, Phill.						x		x
Strophomena rhomboidalis, Wahl.								x
,, var. *analoga*, Phill.								x
,, var. *distorta*, J. de C. Sow.						x		
Dielasma (*Terebratula*) *hastata*, Sow.						x		x
,, ,, *sacculus*, Mart.						x		x
,, ,, *Gillingensis*, Dav.						x		x
,, ,, *vesicularis*, de Kon.						x		x
Lamellibranchiata (Monomyaria).								
Anomia antiqua, Sow.					x			x
Avicula concinna, M'Coy.					x			
,, *decussata*, M'Coy.					x			
,, *lævigata*, M'Coy.				x				
Aviculopecten cœlatus, M'Coy.					x			
,, *concentricostriatus*, M'Coy.					x			x
,, *consimilis*, M'Coy.						x		x
,, *interstitialis*, Phill.					x			
,, *ovatus*, M'Coy.							x	
,, *duplicicosta*, M'Coy.								x
Entolium (*Pecten*) *Sowerbii*, M'Coy.					x			
Posidonomya corrugata, Ether.				x				
Pteronites regularis, Ether.					x			

	Highfield Limestone.			Lower Linn Limestone and Shale.	Shale below Upper Linn Limestone.	Upper Linn Limestone.		
	Swindridge.	Golderaig.	Girthill.			Bourtrapping.	Glencart.	Linn Spout.
Lamellibranchiata (Dimyaria).								
Arca arguta, de Kon.					x			x
Schizodus (*Axinus*) *carbonarius*, Portl.					x			
,, ,, *deltoideus*, Phill.					x			
Cardiomorpha oblonga, Sow.					x			
Conocardium armatum, Phill.								x
Cypricardia striato-lamellosa, de Kon.					x			
Edmondia oblonga, M'Coy.			x		x			
Nuculina (*Leda*) *oblonga*, M'Coy.					x			
,, ,, *attenuata*, Flem.	x		x		x			
Leptodomus costellatus, M'Coy.	x				x			
Nucula gibbosa, Flem.	x	x	x		x	x	x	x
,, *acuta*, Sow.					x			
,, *lineata*, Phill.							x	
Modiola elongata (?), Phill.	x				x			
,, *divisa*, M'Coy.					x			
Allorisma (*Myacites*) *sulcata*, Flem.	x		x		x			
Sanguinolites subcarinatus, M'Coy.				x				
Ungalina, sp. (?).							x	
Venus (?), sp. (?).							x	
Gasteropoda.								
Capulus (*Platycerus*) *vetusta*, Sow.							x	
Entalis (*Dentalium*) *priscum*, Goldf.	x		x		x		x	
,, ,, *Dalryense*, J. Young.	x							
,, ,, *inornatum*, M'Coy.	x				x		x	
,, ,, *Scoticum*, J. Young.	x							
Euomphalus acutus, Sow.								x
,, *serpula*, de Kon.							x	
Schizostoma (*Euomphalus*) *carbonarius*, Sow.	x		x		x		x	
Loxonema Lefebvrei, Lév.								x
,, *rugifera*, Phill.						x	x	
,, *scalaroidea*, Phill.	x							
,, *brevis*, M'Coy.			x		x			
Macrochilina (*Macrocheilus*) *imbricatus*, Sow.	x						x	
,, ,, *acutus*, Sow.	x				x		x	
Polyphemopsis(*Macrocheilus*)*fusiformis*, Sow.	x						x	
Natiria (*Naticopsis*) *lirata*, Phill.							x	
Naticopsis plicistria, Phill.					x			
,, *variata*, Phill.	x		x		x		x	
,, *canaliculata*, M'Coy.								x
Tychonia(*Naticopsis*)*Omaliana*, de Kon.	x							
Aclisina (*Murchisonia*) *striatula*, de Kon.	x		x				x	
Pleurotomaria altavittata, M'Coy.					x			

	Highfield Limestone.			Lower Linn Limestone and Shale.	Shale below Upper Linn Limestone.	Upper Linn Limestone.		
	Swindridge.	Goldcraig.	Girthill.			Bourtrapping.	Glencart.	Linn Spout.
Gasteropoda—*Continued.*								
Agnesia (*Pleurotomaria*) *acuta*, Phill.							x	
,, ,, *contraria*, de Kon.			x					
Ptychomphalus (*Pleurotomaria*) *monilifera*, Phill.	x		x		x			
,, ,, *Frenoyana*, de Kon.							x	
Baylea (*Pleurotomaria*) *Yvanii*, Lév.							x	
Mourlonia ,, *granulata*, de Kon.							x	
,, ,, *interstrialis*, Phill.							x	
Strobæus (*Elenchus*) *antiquus*, M'Coy.							x	
,, ,, *subulatus*, M'Coy.							x	
Turbonitella (*Turbo*) *biserialis*, Phill.							x	
Microdoma (*Trochus*) *biserratus*, Phill.	x							
Niso Smithiana, J. Young, sp. nov.							x	
Polyphemopsis (*Eulima*) *Phillipsiana*, de Kon.	x							
Heteropoda.								
Bucania (*Bellerophon*) *cornu-arietis*, Sow.		x						x
,, ,, *decussata*, Flem.	x		x	x	x			
Waagenella ,, *Dumontii*, D'Orb.								x
Euphemus ,, *Urei*, Flem.	x		x	x	x			
Porcellia puzo, Lév.							x	x
Cephalopoda.								
Orthoceras attenuatum, Flem.		x			x		x	x
,, *cinctum*, Sow.			x		x		x	x
,, *undatum*, Flem.					x			
,, sp. (?).							x	
,, *cylindraceum*, Flem.		x	x					
Cyrtoceras Gesneri, Mart. (fragment).							x	
Goniatites striatus, Sow.	x		x					
Nautilus nodiferus, Armst.						x	x	x
,, *quadrata*, Flem.		x						x
,, sp. (?).								x
Pisces.								
Tomodus convexus, Ag. (Syn. *Cochliodus magnus*, Ag.)	x	x						x
Deltodus, sp. (?).	x							
Helodus didymus, Ag.		x	x					x
,, *lævissimus*, Ag.		x				x		x
Acrolepis Rankinei, Ag.	x							
Petalodus Hastingsiæ, Owen.	x	x				x	x	x
Pœcilodus, sp. (?).							x	
Cladodus mirabilis, Ag.								x

Note.—I am indebted for the greatest number of the *Gasteropoda* found in the Glencart column to the list by Mr. John Young, F.G.S., in "Notes on the Fossils found in a thin bed of impure limestone at Glencart, near Dalry, Ayrshire." *Proc. Nat. Hist. Soc. Glasgow*, Vol.. V. p. 234 (1883).

No. III.—The Parallel Roads of Lochaber; the Problem, its Conditions and Solutions. By William Jolly, F.R.S.E., F.G.S., *V.P.*

[Read 14th May, 1885.]

[Summary.]

The author thought the subject of perennial interest to all geologists, on account of both its intrinsic importance and the eminent men who had written of it. The true solution could not yet be said to have been *finally established*, and elaborate papers were still appearing at intervals, advocating rival theories. His aim was to state the problem, explain the solutions offered, give its bibliography, criticise the theories, and develop more fully the one he adopted. He first described the locality of the Roads in Glen Roy, Glen Spean, Glen Gluoy, and Glen Laggan, all at the south end of the Great Glen. Their unique and striking aspect was such as to draw the attention of the primitive Celts. They had received several names. They were known in Gaelic as *Na Casan*, literally The Feet, hence Footpaths, of which the English *Roads* was a literal translation. Campbell of Islay's rendering, "The Bends," the late Rev. Mr. McGregor, the Gaelic scholar, of Inverness, thought fanciful, and without foundation. They were also variously called "roads," "lines," "shelves," "parallels," etc. The highest of those recognized is in Glen Gluoy, at 1,172 feet, another existing there at 964; the three chief in Glen Roy stand at 1,148, 1,067, and 855; the lowest sweeping round into Glen Spean at the same level. A possible Road, discovered by Darwin in 1838, in Glen Laggan, above the Loch Laggan Locks, is 1,300 feet high. Their breadth varies from 40 to 70 feet, giving an average of 60. They slope towards the valley at an angle of from 5 deg. to 30 deg., the hill face being inclined from 25 deg. to 40 deg.

By means of a printed diagram, which enhanced the clearness of the exposition, Mr. Jolly then explained the Conditions of the Problem, all of which must be satisfied by any theory claiming to be the true solution, as follow :—

A.—The Conditions of the Problem.

I.—*The Peculiar Form and Character of the Roads.*

1. Their general horizontality and parallelism.
2. Their general equality of width, (*a*) in the course of the same line, and (*b*) in relation to each other.

3. Their general continuity.

4. Their stair-like form, as of parallel layers laid successively on each other on the hill side; the highest being closest to the hill: as originally pointed out and sketched by Macculloch.

5. Their sloping towards the valley.

6. Their being proportionately narrower where they are steeper.

7. Their general absence where solid rock protrudes, and where the slope is exceptionally flat.

8. The *debris* of the hill, above and below the Roads, sloping more or less at the angle of repose.

II.—*Their Composition.*

9. The absence of rounded, water-worn stones along them; and the general greater or less angularity of those found.

10. Their consisting of the same *débris* as the rest of the hill-face, and not of transported matter.

11. The absence of cliffs, caves, or rock-notching, or any deep erosion, along their course—with rare exceptions.

III.—*Their Distribution.*

12. Their sudden endings in all cases, without greater accumulations of *débris*, or other indications of the cause of the same.

13. The symmetrical disappearance of the same lines at points opposite each other, in the same and contiguous valleys.

14. The outward extension of the Roads, in the same and contiguous valleys, according to their lesser altitude.

15. Their occasional disappearance for considerable distances.

16. Their different altitudes in different glens; and the absence of the same lines in neighbouring glens.

17. Their being confined to Glen Roy and neighbourhood.

IV.—*Their Relations.*

18. The existence of cols in connection with, and slightly lower than, each of the four main Roads.

19. The existence of other lines of a different character, above and below the Roads. (Dwelt much on by Chambers.)

20. The existence of much terraced *débris*, below the Roads, in the bottoms of the valleys containing them.

21. The relation of the Roads to the marked glaciation of the district and its abundant remains.

B.—The Bibliography of the Problem.

Mr. Jolly then expounded, by means of another diagram, the various Theories proposed to satisfy these Conditions, and account for the Roads; naming the writers advocating them, and the various works which they had written, with their dates. All these are given here in the following table:—

	THEORIES.	WRITERS.		WORKS.
By man —Human.	Fingal	Old inhabitants.		
	Hunting roads of kings ...	Old inhabitants.		
	Aqueducts for irrigation ...	Pennant	1769	Pennant's "Tour," 1771.
		Playfair	1816	Proc. Roy. Soc. Edin., 1816.
By a flood —Diluvial		Sir Geo. S. Mackenzie	1848	Edin. Phil. Journal, Jan. 1848.
	... ...	Prof. Rogers	1861	Lect., Roy. Inst. London, March, 1861.
By the sea—Marine.		Darwin	1839	London Phil. Trans., 1839.
		Lyell (visited 1825) ...	1841	"Elements of Geology."
		Chambers	1848	"Ancient Sea Margins."
		Rev. R. Boog Watson	1866	Quar. Jour. Geol. Society, February, 1866.
	... ...	Prof. Nicol	1869	Quar. Jour. Geol. Society, August, 1869.
		Campbell of Islay ...	1877	"Parallel Roads of Glen Roy," (privately printed.)
		Macfadzean	1882	"Parallel Roads of Glen Roy." (Menzies, Edin.)
By a lake—Lacustrine.	Nature of dam not stated ...	Macculloch	1817	Trans. Geol. Soc. Lond., 1st series, vol. iv.
		Bryce,...	1850	Proceedings of Phil. Soc. Glasgow.
		Lubbock	1868	Quar. Jour. Geol. Society, May, 1868.
		Babbage	1868	Quar. Jour. Geol. Society, August, 1868.
		Dakyns	1879	Geol. Mag., Dec., 1879.
	Dam of *débris* —detrital dam.	Dick-Lauder	1823	Trans. Roy. Soc. Edin., vol. ix.
		Milne Home	1847	Proc. Roy. Soc. Edin., 1847.
		Do.	1876	Trans. Roy. Soc. Edin., vol. xxvii., 1876.
		Do.	1877	Trans. Roy. Soc. Edin., vol. xxviii., part i., 1877.
	Dam of ice—glacial dam.	Agassiz (visited 1840)	1842	Quar. Jour. Geol. Society, vol. iii., 1842; "Atlantic Monthly," June, 1864. (Both by Agassiz.)
		Buckland (do.)	1842	
		James Thomson ...	1848	Edin. New Phil. Jour., vol. xlv.
		Jamieson	1863	Quar. Jour. Geol. Society, vol. xix., January, 1863.
		Darwin	1863	In private letters, etc.
		Lyell	1863	"Antiquity of Man."
		Archibald Geikie ...	1865	"Scenery and Geology of Scotland."
		Jolly	1873	Trans. Geol. Soc. Edin., April, 1873; also in Milne Home's paper, Trans. Roy. Soc. Edin., 1876.
		James Geikie	1873	"The Great Ice Age."
		Sir Henry James ...	1874	"Parallel Roads of Lochaber," Ord. Survey Office.
		Rev. T. Brown... ...	1876	Proc. Roy. Soc. Edin., vol. viii., March, 1876.
		Tyndal	1876	Roy. Inst., June, 1876; "Pop. Science Review," October, 1876.
		Colin Livingston ...	1878	Trans. of Inverness Field Club, vol. i. p. 101.
		Prestwich	1879	Roy. Soc. London; *Nature*, May 29, 1879, in abstract; Lond. Phil. Trans., 1880, in full.
		Jolly	1880	*Nature*, May 20, 1880; Trans. of Inverness Field Club vol. i. p. 287.

C.—The Solutions of the Problem.

I. After referring to the Traditional theories of Fingal and the Hunting Roads, adopted by Pennant, in his remarkable "Tour," published in 1771, Mr. Jolly told how Playfair had seen similar appearances exhibited by irrigation works at Brieg, in the Valais, which suggested to him his curious solution.

II. The Diluvial theory held that the Roads were caused by an immense flood from the Atlantic, through a sinking of the West Coast, rushing impetuously up these valleys. There was no use seriously criticising this theory, though adopted in 1861 by Prof. Rogers of Glasgow; the theory being suggested to him by his thinking that the Roads were higher at the upper ends of the glens than at the lower, which had been found not to be the case.

III. The Marine theory had had many able supporters, from its first suggestion by Darwin in 1839, to Campbell of Islay in 1877, and Mr. Macfadzean, of the Inland Revenue, in Glasgow, who had published a large and learned volume (Edinburgh, Menzies) so recently as 1882. The greatest exponent of this theory was Robert Chambers, in his "Ancient Sea Margins" published in 1848, who held that these lines were nothing but sea beaches, similar to those found so plentifully all over the country. He contended that other lines in these same glens were of the same kind; but these had been shown by Mr. Jolly, in 1873, to be entirely different in character, outline, and composition, and were probably moraines; (*Trans. Geol. Soc. Edin.*, 1873.)

Mr. Jolly then traversed the conditions of the Problem laid down above, and showed how this theory violated, or failed satisfactorily to account for, Nos. 1, 4, 5, 7, 9, 11, 12, 13, 14, 15, 16, 17, 18, 19, and 21; by each of which it may be tested.

IV. The Lacustrine theory would not be found open to the same objections. The great difficulty here was the nature of the dam, or barrier, that confined the waters of the lakes, of which the famous Roads were the successive shores or beaches. This theory was propounded in 1817 by the far-seeing Macculloch, the eminent geologist and early delineator of Highland scenery and geology; but he, along with others, had not condescended on the kind of barrier required.

Two styles of dam had been contended for by different writers, the one of detritus, the other of ice. The Detrital dam, first suggested by Dick Lauder in 1823, had been adopted by Milne Home, who

accompanied Robert Chambers to the region in 1847. He had written of it then, and twice since, with an amount of observation and detail that was of great and permanent value. These writers held that the lakes were contained by huge banks of *debris*, deposited by the sea and other causes, similar to those existing abundantly in many parts of the country. There was no doubt whatever that a large number of lakes, past and present, had been dammed back by such barriers in many places. But if the Roads were so formed, why were not such remarkable lines (whose character was unique) found elsewhere? Mr. Jolly here examined this theory in detail, in connection with the requisite Conditions, and held that it failed to satisfy many of them. How were these barriers so conveniently deposited at the required points, when the Great Glen, and the other valleys, were, according to Milne Home, filled with similar detritus? In the other lakes adduced by him, the outlets were *over the debris*, gradually wearing it away, while here the outlets existed at the upper ends, flowing over hard rock. The Roads ended abruptly on the hill face, with no remains of the asserted barriers heaped up *at their extremities*, as might be expected, and as was almost universal. How were the requisite great accumulations so effectively removed, reaching, as these must have done, to above 1,300 feet? The successive roads were on the same hill-face, so that the damming *debris* must have been wholly removed between the lines at their lower ends, before the new beaches were laid down. Mr. Jolly entered into other difficulties attending this theory, and finally concluded against it.

D.—The Glacial Theory, as adopted by the Author.

The Glacial theory was started by Agassiz, the great Swiss, who had been accustomed to see the work of glaciers, after a visit paid to Lochaber in company with Buckland, in 1840. It has had the greatest number of adherents, Darwin and Lyell having also given up the Marine theory for it. Its chief exponent was Jamieson of Ellon, in an admirable paper published in 1863. By means of a Survey map, Mr. Jolly entered into a careful explanation of the glaciation of the region. He held that the Roads were produced by lakes dammed back by glacial ice, filling the lower parts of the valleys up to the ends of the Roads, and gradually retreating with the ameliorating climate, *at the last stage of the second portion* of the Glacial epoch, immediately before the final disappearance of

local glaciers from Scotland. The abundant rolled *debris* at the bottom of these valleys was laid down by former glaciers, and re-sorted by the sea during the great depression in the *middle* of the Glacial period.

Mr. Jolly entered into a detailed description of the peculiar configuration of the Ben Nevis Range, with its parallel system of valleys opening out, on the south, to the close, deep Glen Nevis and its eastern continuation, and, on the north, to the broad Glen Spean, and broader Glen More. The peculiarity of Glen Spean was that it would receive not only the abundant ice from the glens opening directly on it on the south, but also the greater part of the ice accumulated in Glen Nevis and its continuation, by the two outlets of Loch Treig and Glen Nevis itself. By this means, and by its special relation to the highest mountains in Scotland, it would receive an unusual supply of ice, equalled by no other valley in the country. This was proved not only by its geographical conformation, but by the superabundant glacial remains in the district, of which Mr. Jolly gave full details.

During the first period of greater glaciation in the Glacial period, the ice from Loch Treig, after entering Glen Spean, turned both eastwards down Loch Laggan, and westwards down the Spean. Glen Roy itself was filled with an overflow ice-stream from the same valley, which *moved out at its head down the Spey*, as shown convincingly by the ice-markings there; and the Great Glen and its side valleys were also swathed in ice. As the climate improved at the *final close* of the Ice period, the glaciers gradually shrank backwards to their sources in the high Nevis glens. From their altitude, and neighbourhood to the vapour-feeding Atlantic, these would be the last in the country to preserve local glaciers. Through its peculiar relations to these glens, Glen Spean would, at that time, be filled from its head to the sea with a great ice-stream, resting on the *debris* already deposited by the sea, etc., and moving slowly downwards. This stream, entering the south end of Glen Roy, dammed back a lake there, fed by its tributary torrents, which has left its traces in the Roads. As the ice gradually shrank in successive steps, the water subsided and the lake extended, as shown by these lines.

Mr. Jolly here pointed out on the map the position of the successive contractions of the ice required to dam the lake, and described the abundant evidences of this last stage of the glaciers

there, in scratchings, carried blocks, boulder clay, etc., and in the splendid horse-shoe moraines of the Treig glacier, lying intact across and along Glen Spean. He held that the lowest Road extended up Loch Treig only a short distance, suddenly ceasing there—and not round the whole lake, as asked by Milne Home and Dick Lauder —an additional remarkable proof in favour of a glacier then filling that basin down to the ends of the Roads, where a dam was necessary.

Similar explanations were given regarding the Glen Gluoy Parallels. The ancient lake in Glen Gluoy was dammed back by a great accumulation of ice then filling the Great Glen, in the bed of the present Loch Lochy. At the mouth of Glen Gluoy, there then existed an immense congestion of ice, caused by the meeting of the ice of the Great Glen itself and that of Loch Arkaig valley, which was filled with a deep ice stream, as proved by its abundant scratches. Part of this congested ice was forced right up Glen Gluoy, during the greater portion of the Glacial period, and went out at its head into Glen Roy, and so along with the Glen Roy ice, down Glen Spey. At the close of the Glacial epoch, the Glen Gluoy ice shrunk down from the head of its glen ; but, remaining stationary for a period, dammed back a lake there at the points where the Roads terminate, and then, like the rest of the ice, vanished with the ameliorating climate that finally obliterated all glaciers from Scotland.

Mr. Jolly had studied the subject for more than fourteen years during his residence in the north, his professional work as Inspector of Schools in the very district giving him unwonted opportunities for examining the phenomena at all points. He hoped shortly to embody his observations and conclusions in two papers—one on the glaciation of the Nevis Mountains, which he had worked out, and the other on the application of the results of this paper to the Glen Roy problem. He had also had the pleasure of traversing the ground carefully with Dr. Milne Home, an excellent mountaineer and painstaking observer. A joint letter of theirs, sent to Sir Henry James, had happily been acted on in an enlightened way, by securing the return to the district of efficient Survey officers to map the whole phenomena, especially important points suggested by them, with a fulness and accuracy greater than usual ; which was a permanent gain to all students of the difficult and much-debated question.

Mr. Jolly concluded with an appeal to the members of the Society to study the fascinating problem on the ground itself.

By means of coloured additions laid over the map, the state of the ice during its successive contractions and stationary positions, at the end of the Glacial epoch, as necessary to fulfil the requisite conditions, was graphically exhibited.

The reader may consult with advantage, for the better understanding of the subject, the admirable maps of the district by the Ordnance Survey, both the six-inch and one-inch, in which the Roads and the related phenomena are accurately and fully laid down; also the special Ordnance selected map of the locality, appended to the paper of Sir Henry James, mentioned above.

No. IV.—Notes on some Fossil Plants collected by Mr. R. Dunlop, Airdrie, from the Lanarkshire Coal-field. By Robert Kidston, F.G.S. With a Plate [No. III.]

[Read April 2nd, 1885, with additions made May, 1886.]

Through the kindness of Mr. Dunlop I have had the opportunity of examining the fossil plants collected by him from several localities in the Lanarkshire Coal-field. The annexed list of species compiled from this collection, though of considerable interest, must not be regarded as a complete representation of the Carboniferous fossil flora of this district; but it contains one or two species which have not been previously recorded from Scotland. I have only to express my hope that Mr. Dunlop will continue his investigations in a field of natural history on which he has so successfully entered. Many of the specimens he has secured are exceedingly fine; of some of the species, they are finer than any I have yet seen from the British Coal-fields.

As it is my intention to work out the distribution of the Carboniferous flora, I am much indebted to Mr. Dunlop for the facilities he has given me in examining his specimens. I shall be very glad if others, who possess specimens of Carboniferous fossil plants, would kindly allow me to examine them, and so assist in working out their distribution; on my part I shall be most happy, as far as I can, to help any who may wish for assistance in the study of this most interesting class of fossils.

It is only possible, by mutual co-operation, to compile a complete list of the Carboniferous fossil plants from an area so large and rich as that of the British Coal-fields.

Calamariæ.

Calamites, Suckow.

Weiss, in his two volumes on *Calamites*,* has contributed so much to our knowledge of the stems and their ramification, the fructification, foliage, and roots of *Calamites*, that this group of fossil plants can no longer be looked upon as that about which we are most ignorant. His first volume deals chiefly with the fructification of *Calamites*, his second treats of the stems, as well as of the foliage and roots, with much additional information in regard to their fructification and systematic position.

The Calamariæ have usually been classed with the Equisetaceæ; but from the examination of their fructification it is seen that there are points in which they clearly differ from the recent *Equisetum*. On the other hand, there are some characters in which *Calamites* have a considerable similarity with the Equisetaceæ, and among recent plants it is certainly with this group they have the greatest affinity.

It would appear that *some* of the fossil cones which have been referred to the Calamariæ show that their upper part bore *microspores*, whilst their lower portion bore *macrospores*, nor are the spores provided with *elaters*, as in *Equisetum*.† But in the order Lycopodiaceæ some members are *heterosporous* and others *isosporous*. For example, *Lycopodium* has only one kind of spore (*isosporous*), while *Selaginella* has both *microspores* and *macrospores* (*heterosporous*). It may, perhaps, be found then that, although some of the cones which are supposed to belong to *Calamites* show a *heterosporous* condition, this may not be of sufficient importance to exclude them from the Equisetaceæ, where the spores are *isosporous*. It is also most probable that the genus *Calamites*, when its fructification is more fully examined, will require to be

* "Steinkohlen-Calamarien. — Part I., Abhandl. zur geologischen Specialkarte von Preussen und den Thüringischen Staaten, band ii., heft i., 1876; "Steinkohlen-Calamarien.—part II.," Abhandl. &c., band v., heft ii., 1884.

† See also Dr. Williamson's papers on the structure of *Calamites* published at various dates in the *Philosophical Transactions*.

separated into many genera; and in this light the genus *Calamites*, as Weiss points out, can only be regarded as of a most provisional nature.

The roots of *Calamites* are those fossils to which Lindley and Hutton applied the name of *Pinnularia*.

From our present standpoint of knowledge, Weiss proposes to divide the genus *Calamites* into the four following groups:—

CALAMITES, Suckow (provisional genus).

Division A. *Furrows on stems alternating at the nodes or joints.*

Group I. *CALAMITINA*, Weiss.

Branch-scars occurring periodically, the nodes bearing scars being separated from each other by a certain number of joints which do not bear branches. In most cases there is a regular increase or decrease in the length of the joints which connect the branch-bearing nodes.

Group II. *EUCALAMITES*, Weiss.

Branch-scars occurring on every joint. The joints are of the same length or of irregularly different lengths.

Group III. *STYLOCALAMITES*, Weiss.

Branch-scars occurring without definite order, subordinate; often long stretches of the stem occur on which the branch-scars are entirely absent. The joints are of equal length or irregularly different.

Division B. *Furrows on the stem not alternating at the nodes or joints.*

Group IV. *ARCHÆOCALAMITES*, Stur (*Asterocalamites*, Schimper; *Calamites*, Brongniart).*

Branch-scars irregularly distributed. Joints unequal in length.

For the purpose of classifying these fossils, the groups proposed by Weiss will be found most useful; but perhaps Nos. I., II., and III. had better be regarded at present as convenient *sections* rather than *genera*. Group IV., on the other hand, is so well

* The fruit of *Archæocalamites* is the *Pothocites Grantonii* of Paterson. See *Ann. & Mag. Nat. Hist.* May 1883, p. 297.

defined, both as concerns its stems and fruit, that it must be regarded as a true *genus* and quite distinct from *Calamites*.

In geological distribution groups I.–III. are characteristic of the Coal-measures; group IV. of the Lower Carboniferous (= Carboniferous Limestone series and Calciferous Sandstone series).

A good deal of discussion has taken place as to whether the exterior surface of the bark of *Calamites* was smooth or furrowed. It appears, as is often the case in such differences of opinion, that both views are correct in part. It now seems clearly proved that the species with thin bark show on their outer surface the characteristic furrows, but, on the other hand, the stems with thick bark show no trace of the furrows on their outer surface. The decorticated stems, however, are always distinctly furrowed, and it is in this condition that *Calamites* most frequently occur. This vexed question, from the careful investigations of Prof. Weiss, seems to be now satisfactorily settled.

Group I. *Calamitina*, Weiss.

Calamites (*Calamitina*) *varians*, Sternberg.

Calamites varians, Sternberg, Vers. ii., p. 50, pl. xii.

Remarks. This specimen belongs to one of the forms of this species, but is not in a good state of preservation.

Locality. Drumgray Coal, Airdrie.

Calamites (*Calamitina*), sp.

Remarks. Unfortunately only a few fragmentary specimens of these plants were collected. They belong to the group of *Calamites* with a thick smooth bark. At the nodes the leaf-scars form a chain of transversely oval contiguous scars, similar to those occurring in *Calamites* (*Calamitina*) *varians*, var. *inconstans*, Weiss ("Steinkohlen-Calamarien," vol. ii. p. 69, pl. xxv.). From the fragmentary nature of the specimens, however, I cannot with any certainty refer them to that species. We can only hope that more perfect examples will soon be found which will enable us satisfactorily to determine the species.

Locality. Blaes between Kiltongue and Drumgray Coals; Whiterigg Colliery, near Airdrie.*

* As the plants from this bed occur in a state of great perfection, to show its exact position I append a section, which was procured for me by Mr. Dunlop from Mr. Prentice, manager of the colliery.

Calamites Cistii, Brongniart.

Calamites Cistii, Brongniart, Hist. d. végét. foss., p. 129, pl. xx.

Locality. Pit near Calder Iron Works, Airdrie.

Group II. *Eucalamites*, Weiss.

Calamites (*Eucalamites*) *ramosus*, Artis.

Pl. III, fig. 1.

Calamites ramosus, Artis, Antedil. Phyt., pl. ii.

Calamites (*Eucalamites*) *ramosus*, Weiss, Steinkohlen-Calamarien, part ii., p. 98, pl. v., figs. 1, 2, pl. vi., pl. vii., figs. 1, 2, pl. viii., figs. 1, 2, and 4, pl. ix., figs. 1, 2, pl. x., fig. 1, pl. xx., figs. 1, 2.

Calamites nodosus, Lindley & Hutton, Foss. Flora, vol. i., pls. xv., xvi.

Annularia radiata, Zeiller, Végét. foss. du terr. houill. de la France, p. 24, pl. clx., fig. 1.

Asterophyllites radiatus, Brongniart, Class. d. végét. foss., p. 35, pl. ii., fig. 7.

Asterophyllites foliosus, Lindley & Hutton, Foss. Flora, vol. i., pl. xxv., fig. 1.

Annularia ramosa, Weiss, "Beobachtungen an Calamiten und Calamarien," *Neues Jahrb.*, vol. ii., 1881.

Section of Strata between the Kiltongue Coal and the Upper Drumgray Coal, showing the Fern-bed (*Stanrigg Colliery, by Airdrie*).

	Ft.	In.
Coal (including 3 inches of gas-coal), ...	1	0
Dark fireclay, ... } Kiltongue, ...	0	5
Coal, ... }	1	4
Fireclay, ...	0	10
Argillaceous schist, ...	5	6
Fireclay, ...	1	1
Coal, ...	0	6
Argillaceous schist, ...	4	10
Sandstone, ...	5	9
Argillaceous shale, ...	1	1
Coal, ...	0	8
Argillaceous shale, ...	3	6
Sandstone, ...	2	5
Argillaceous schist (*Fern-bed*), ...	2	6
Argillaceous shale, ...	3	3
Sandstone, ...	3	3
Argillaceous schist, ...	1	8
Shale (dark), studded with *Anthracosia*, ...	1	0
Argillaceous shale, ...	0	8
Sandstone (hard), ...	5	6
Argillaceous shale, ...	0	10
Coal (Upper Drumgray), ...	2	0

Remarks. This species is very fully described by Weiss. The little branches, with verticillate leaves, each of which terminates in a sharp apex and is also tapered from its centre to its point of attachment with the stem, and which have been described as *Annularia radiata*, are now known to be the foliage of this plant. The fruit is also described by Weiss. This and the following species are the two most common *Calamites* in the Scotch Coal-measures.

Localities. Blaes between Kiltongue and Drumgray Coals, Whiterigg, near Airdrie; Pits, Airdrie; Shettleston, near Glasgow; Bent Colliery, about 1½ mile E. of Bothwell; Mount Vernon; Inkerman Pit, Airdrie; Calderbank, near Airdrie; Bellsdyke Pit, Airdrie.

Group III. *Stylocalamites*, Weiss.

Calamites (*Stylocalamites*) *Suckowii*, Brongniart.

Calamites Suckowii, Brongniart, Hist. d. végét. foss., p. 124, pl. xiv., fig. 6, pl. xv., figs. 1-6, pl. xvi., figs. 2, 3 (? fig. 1).

Calamites Suckowii, Zeiller, Végét. foss. du terr. houil. de la France, p. 12, pl. clix., fig. 1.

Calamites (*Stylocalamites*) *Suckowii*, Weiss, Steinkohlen-Calamarien, part ii., p. 129, pl. ii., fig. 1, pl. iii., figs. 2, 3, pl. iv., fig. 1, pl. xxvii., fig. 3.

Localities. Pits near Airdrie; Bent Colliery, about 1½ mile E. of Bothwell; Inkerman Pit, near Airdrie; Pit near Calder Iron Works, near Airdrie; Calderbank, near Airdrie.

Calamocladus, Schimper.

Calamocladus equisetiformis, Schlotheim, sp.

Calamocladus equisetiformis, Schimper, Traité d. paléont. végét., vol. i., p. 324, pl. xxii., figs. 1-3.

Asterophyllites equisetiformis, Brongniart, Prodrome, p. 159; Germar, Vers. v. Wettin u. Löbejun, p. 21, pl. viii.

Hippurites longifolia, Lindley & Hutton, Fossil Flora, vol. iii., pls. cxc., xci.

Casuarinites equisetiformis, Schlotheim, Flora d. Vorwelt, p. 30, pl. i., figs. 1, 2, pl. ii., fig. 3.

Remarks. A very fine specimen of this species has been collected. It shows the remains of four branches, the longest of which, however, is incomplete, but measures 8 inches and bears seventeen whorls of leaves. From the position in which the branches lie to each other they have evidently been attached to a common stem. Each whorl contains about thirty leaves.

Localities. Bent Colliery, about 1½ mile E. of Bothwell; Blaes between Kiltongue and Drumgray Coals, Whiterigg, near Airdrie; Calderbank, near Airdrie.

Calamocladus grandis, Sternberg, sp.

Calamocladus grandis, Schimper, Traité d. paléont. végét., vol. i., p. 325.
Bechera grandis, Sternberg, Vers. i., fasc. iv., p. xxx., pl. xlix., fig. 1.

Remarks. Most probably this species is not distinct from *Calamocladus equisetiformis*, Schl. sp.

Locality. Bent Colliery, about 1½ mile E. of Bothwell.

ANNULARIA, Sternberg.

Annularia patens, Sauveur, sp.

Pl. III., fig. 2.

Asterophyllites patens, Sauveur, Végét. foss. du. terr. houil. de la Belgique, pl. lxix., fig. 4.

Description. Stem faintly striated longitudinally; internodes varying in length (according to the age of the specimen). Leaves whorled, numerous (8–16 in a whorl), long, linear, narrow, single-nerved, and terminating in a sharp point; basal portion of leaf not contracted. The leaves vary in length from $\frac{3}{10}$ of an inch on the smaller branches to nearly an inch on the larger, and in width from $\frac{1}{20}$ to $\frac{1}{25}$ of an inch. From the leaf-whorls are given off lateral branchlets.

Remarks. Of this species the only figure with which I am acquainted is that given by Sauveur, which only shows a portion of a whorl of leaves. Unfortunately no description accompanies his sketch.

The leaves are long in proportion to their breadth and of equal width throughout, and this, in connection with their not being contracted at their base, easily distinguishes *Annularia patens* from *Annularia radiata*. The leaves are generally rather longer than one and a half times the length of the internodes. On the smaller branches, of course, the leaves and internodes are smaller than on the larger branches, but they usually hold the same proportional relationship to each other in size. One small example shows a lateral branch springing from the axil of one of the leaves; but none of the other nodes of this example gives rise to branches. From this its mode of ramification appears to be irregular.

Although this species has not been previously recorded from Britain, I have seen it, in addition to the Airdrie locality, from the Coal-measures, Furnace Bank Pit, Old Sauchie, near Alloa,

and Devonside, Tillicoultry, Clackmannanshire; and Blairpoint, Dysart, Fife.

Localities. Pit, near Airdrie; Calderbank; Bellsdyke Pit, near Airdrie.

PALÆOSTACHYA, Weiss.

Palæostachya gracillima, Weiss.

Pl. III., fig. 3.

Palæostachya gracillima, Weiss, Steinkohlen-Calamarien, part II., p. 184, pl. xviii., fig. 1. 1884.

Remarks. Several specimens of this cone have been collected at Calderbank, one of which is given at fig. 3. Almost none of the examples show the complete length; the largest of those figured, which however is imperfect, measures $2\frac{1}{2}$ inches.

The sporangia are situated in the axils of the bracts, and in many cases the sporangiophores, to which the sporangia have been attached, are clearly exhibited. An enlarged view of a sporangium is given at fig. 3*a*, where are shown the *sporangium* (*a*), the *sporangiophore* (*b*), the *bract* (from the axil of which the sporangiophore springs) (*c*), and the axis of the cone (*d*).

The characters of the genus are very well illustrated in some of these specimens.

The necessity of collecting *all fragments* of fructifications cannot be too much emphasized, as often on apparently badly preserved specimens the arrangement of the sporangia is more clearly shown than on more perfect examples where the bracts remain in position.

Locality. In debris taken out of the foundation for the new Caledonian Railway Bridge, Calderbank, about two miles south of Airdrie.

CALAMOSTACHYS, Schimper.

(?) *Calamostachys longifolia*, Weiss.

Pl. III., fig. 4.

Calamostachys longifolia, Weiss, Steinkohlen-Calamarien, part I., p. 52, pl. x., figs. 2 and 3. 1876.

The cones placed here, though smaller, have all the characters of those figured by Weiss in his Steinkohlen-Calamarien, part I., pl. x, figs. 2 and 3, the peculiar character of which, Weiss thinks, results from a malformed growth, perhaps brought about by insects, but from whatever cause, he is inclined to regard the two specimens figured by him on his plate x., figs. 2 and 3, as monstrosities.

The Calderbank specimens, especially that figured at 4*a*, show the verticillate arrangement of the leaf-scars similar to that occurring on Weiss' specimens, as also some of the very narrow leaves still attached. On our figure 4 the cones are seen to spring from *alternate* nodes of a calamitic stem and on the counterpart of this specimen, from the fortuitous manner in which a small part of the matrix lifted up, a third cone is seen to spring from the node of the middle group of cones. The position of this third cone is indicated at fig. 4 in dotted lines.

This example (fig. 4) has a great resemblance to *Volkmannia polystachya*, Sternberg (Vers. i., fasc. 4, p. xxx., pl. xli., fig. 1*a*). There the cones are developed in groups of four (as has probably been the case with our specimen), and some of the cones on Sternberg's plant also show the verticils of little tubercles, but the imperfect preservation of his example and the diagrammatic style of his figure do not afford very satisfactory grounds for comparison.

I have figured the Calderbank specimens with the object of bringing them before collectors in the hope that they may carefully preserve all such examples.

Locality. In debris taken out of the foundation for the new Caledonian Railway Bridge, Calderbank, about two miles south of Airdrie.

Calamitic Cones.

Several cones, probably referable to *Calamites* or *Sphenophyllum*, have also been collected, but their state of preservation does not admit of any satisfactory determination.

Localities. Calderbank, Inkerman, and Gartlee Pits, near Airdrie.

(?) Rhizocarpeæ.

Sphenophyllum, Brongniart.

Sphenophyllum cuneifolium, Sternberg, sp.

Sphenophyllum cuneifolium, Zeiller, Végét. foss. du. terr. houil. de la France, p. 30, pl. clxi., figs. 1, 2.
Sphenophyllum erosum, Lindley & Hutton, Fossil Flora, vol. i., pl. xiii.
Rotularia cuneifolia, Sternberg, Vers. i., fasc. ii., p. 33, pl. xxvi., fig. 4.
Rotularia pusilla, Sternberg, Vers. i., fasc. iv., p. xxxii.

Localities. Pit, Airdrie; Bent Colliery, about 1½ mile E. of Bothwell; Calderbank, near Airdrie.

Sphenophyllum cuneifolium, var. saxifragæfolium, Brongniart.
S. cuneifolium, var saxifragæfolium, Coemans & Kickx., *Bull. l'Acad. roy. Belgique*, vol. xviii., p. 151, pl. i., fig. 6.

Localities. Whiterigg Pit, near Airdrie; Calderbank, near Airdrie.

Filicaceæ.

Sphenopteridæ.

Renaultia, Zeiller.

Renaultia microcarpa, Lesquereux, sp.

Sphenopteris microcarpa, Lesquereux, Coal Flora of Pennsyl., p. 280, pl. xlvii., fig. 2.
Sphenopteris microcarpa, Kidston, (*in part*) *Ann. & Mag. Nat. Hist.*, ser. 5, vol. x., p. 9, pl. i., figs. 9-14.
Renaultia (*Sphen.*) *microcarpa*, Zeiller, *Ann. d. Sciences Nat.*, 6e sér., Bot. vol. xvi., p. 185.

Remarks. The fruit of this species was first described by Lesquereux, but later and more fully by myself. It consists of small oval exannulate sporangia which are situated at the extremities of the veins.

Localities. Roof of Kiltongue Coal, Mount Vernon; Pit, near Airdrie.

Sphenopteris, Brongniart.

Sphenopteris trifoliolata, Artis (not Brongniart).

Sphenopteris trifoliolata, Brongniart, Prodrome, p. 50.
Filicites trifoliolatus, Artis, Antedil. Phyt., pl. xi.

Remarks. Some of the specimens I refer to this species are in a good state of preservation for a satisfactory determination; hence the record of its occurrence in Lanarkshire is now corroborated.

Localities. Bent Colliery, about $1\frac{1}{2}$ mile E. of Bothwell; Foxley, Shettleston; Caledonian Railway Cutting, Airdrie.

Sphenopteris obtusiloba, Brongniart.

Sphenopteris obtusiloba, Brongniart, Hist. d. végét. foss., p. 204, pl. liii., fig. 2*.
Sphenopteris irregularis, Andræ, Vorwelt Pflanzen, p. 24, pl. viii., pl. ix., fig. 1.
Sphenopteris irregularis, Sternberg, Vers. ii., p. 63, pl. xvii., fig. 4, p. 152, pl. ix., fig. 7.
Sphenopteris latifolia, Lindley & Hutton, Fossil Flora, vol. ii., pl. clvi., vol. iii., pl. clxxviii.

Sphenopteris trifoliolata, Brongniart (not Artis), Hist. d. végét. foss., p. 202, pl. liii., fig. 3 (excl. refer.).

Remarks. Exceedingly fine specimens of this fern were collected.

Localities. Blaes between Kiltongue and Drumgray Coals, Whiterigg, near Airdrie; Foxley, Shettleston.

Sphenopteris furcata, Brongniart.

Sphenopteris furcata, Brongniart, Hist. d. végét. foss., p. 179, pl. xlix., figs. 4, 5.

Diplothmema furcatum, Zeiller, Végét. foss. du terr. houil. de la France, p. 45, pl. clxii., fig. 3.

Localities. Cutting, new Caledonian Railway, Airdrie; Black Pit, Longriggend, Slamannan; Calderbank, near Airdrie.

(?) *Sphenopteris* (*Hapalopteris*) *Schützei*, Stur.

Pl. III., fig. 5.

Hapalopteris Schützei, Stur. Die Carbon-Flora der Schatzlarer Schichten, p. 56, pl. xli., figs. 1-4. 1885.

Remarks. It is with considerable doubt that the fern shown at fig. 5 is placed under *Sphenopteris Schützei*, Stur. Several fruiting examples have been collected, but of what we regard as its barren condition, the small fragment given at fig. 5*b* is the most perfect. This has a great resemblance to Stur's *Sph. Schützei*, but notwithstanding the full description he gives of his fern, without accompanying good figures, it is almost impossible to identify many of the small pinnuled sphenopteroids.

The barren pinnules on the Calderbank examples are oval-lanceolate, and divided into from 4 to 5 linear obtuse segments, which in some cases are notched. The fruiting specimens possess the same characters, but are somewhat laxer, and bear sporangia at the extremities of the pinnule segments, into each of which extends a vein.

I have not been able to discover the ultimate structure of the sporangia, whether annulate or exannulate. One peculiar feature in regard to these fossils consists in the sporangia always adhering to the counterpart, leaving only a hollow depression on the fossil to mark their position.

Locality. In debris brought up while digging the foundation to the new Caledonian Railway Bridge, Calderbank, about 2 miles south of Airdrie.

Sphenopteris (*Hapalopteris*) *amœna*, Stur.

Hapalopteris amœna, Stur, Die Carbon. Flora d. Schatzlarer Schichten, p. 52, pl. xli., fig. 7. 1885.

Sphenopteris microcarpa, Kidston (not Lesqx) *in part*, *Proc. Roy. Phys. Soc. Edin.*, vol. vii., pl. i., figs. 7 and 8. 1882.

Remarks. This species (*Sphen. amœna*) I previously united with *Renaultia* (*Sphenopteris*) *microcarpa*, Lesqx, regarding it as only a variety of that fern.

What I described as the fruit of *Renaultia microcarpa* in the *Proceedings of the Roy. Phys. Soc. Edin.*, vol. vii., pl. i., figs. 9–14, belongs however to *R. microcarpa*, and not to *Sphenopteris* (*Hapalopteris*) *amœna*.

Locality. Foxley, near Shettleston.

Sphenopteris, sp.

Remarks. The specimens I place here have a great resemblance to *Sphenopteris rotundifolia*, Andræ ("Vorweltliche Pflanzen," p. 37, pl. xii.), but, as it is necessary to use great care in recording the occurrence of a species, I will refrain at present from applying the specific name of "*rotundifolia*, Andræ," to them, and await further evidence before definitely determining this fern. But to whichever species this plant belongs, these examples are the first I have seen.

Locality. Blaes between Kiltongue and Drumgray Coals, Whiterigg, near Airdrie.

URNATOPTERIS, Kidston.

(?) *Urnatopteris tenella*, Brongniart, sp.

Urnatopteris tenella, Kidston. *Quart. Journ. Geol. Soc.*, vol. xl., p. 594.

Sphenopteris tenella, Brongniart, Hist. d. végét. foss., p. 186, pl. xlix., fig. 1.

Remarks. The specimens included here are somewhat larger in all their parts than typical *U. tenella;* in other respects they do not differ.

They have, however, a considerable resemblance to *Sphenopteris herbacea*, Boulay, which has little to distinguish it from *U. tenella*, except its slightly larger size.

Locality. Calderbank, about two miles south of Airdrie.

MARIOPTERIS, Zeiller.

Mariopteris, Zeiller, *Bull. Soc. Geol. de France*, 3e sér., vol. vii., p. 92; Végét. foss. du terr. houil. de la France, p. 68 (from vol. iv., de l'explication de la carte géologique de la France, 1880).

This genus was founded by Zeiller to include certain ferns which, among other characters, are distinguished by a peculiar dichotomizing of their pinnæ. The primary pinnæ are attached to the rachis by a naked stalk, which bifurcates at a very obtuse angle; each of the forks of this first dichotomy again bifurcates, forming the secondary pinnæ, on which are borne the tertiary pinnæ, which in turn support the pinnules.

Mariopteris latifolia, Brongniart, sp.

Mariopteris latifolia, Zeiller, *Bull. Soc. Géol. de France*, 3e sér., vol. vii., p. 92, pl. vi.

Sphenopteris latifolia, Brongniart, Hist. d. végét. foss., p. 205, pl. lvii., figs. 1-4.

Locality. Roof of the Kiltongue Coal, Mount Vernon.

Mariopteris muricata, Schlotheim, sp.

Mariopteris muricata, Zeiller, *Bull. Soc. Géol. de France*, 3e sér., vol. vii., p. 92.

Pecopteris muricata, Brongniart, Hist. d. végét. foss., p. 352, pl. xcv., figs. 3, 4, and pl. xcvii.

Filicites muricatus, Schlotheim, Flora d. Vorwelt, p. 54, pl. xii., figs. 21 and 23.

Localities. Bent Colliery, about 1½ mile E. of Bothwell; Whiterigg Colliery, near Airdrie; Calderbank.

Mariopteris nervosa, Brongniart, sp.

Mariopteris nervosa, Zeiller, Végét. foss. du terr. houil. de la France, p. 69, pl. clxvii., figs. 1-4.

Pecopteris nervosa, Brongniart, Hist. d. végét. foss., p. 297, pl. xciv., and pl. xcv., figs. 1, 2.

Pecopteris nervosa, Lindley & Hutton, Fossil Flora, vol. ii., pl. xciv.

Remarks. Some of the specimens are very fine.

Localities. Bent Colliery, about 1½ mile E. of Bothwell; Calderbank; Pit near Calder Iron Works, Airdrie.

NEUROPTERIS, Brongniart.

Neuropteris heterophylla, Brongniart.

Neuropteris heterophylla, Brongniart, Hist. d. végét. foss., p. 243, pl. lxxi., and pl. lxxii., fig. 2.

Neuropteris heterophylla, Zeiller, Végét. foss. du terr. houil. de la France, p. 49, pl. clxiv., figs. 1, 2.

Neuropteris Loshii, Brongniart, Hist. d. végét. foss., p. 242, pl. lxxii., fig. 1, and pl. lxxiii.

Cyclopteris trichomanoides, Brongniart, Hist. d. végét. foss., p. 49, pl. lxi., *bis*, fig. 4.

Remarks. Some exceedingly fine specimens of this fern, from blaes lying between the Kiltongue and Drumgray Coals, which were brought up while driving a road, were collected by Mr. Dunlop at Whiterigg Pit, near Airdrie. These examples are the finest British specimens I have seen.

Several specimens of *Cyclopteris trichomanoides*, Brong., which at one time was supposed to form a distinct species of a different genus, have also been collected. These peculiar cyclopteroid pinnules were attached to the main rachis of the fern, and a figure showing their relation to the other parts of the frond has been given by Röhl (Vers. d. Steink.-Form. Westphalens, pl. xvii.). *Neuropteris heterophylla* and *Neuropteris Loshii* are now known to represent only different portions of the same species.

Localities. Blaes between Kiltongue and Drumgray Coals, Whiterigg, near Airdrie; new Caledonian Railway Cutting, Airdrie; roof of Kiltongue Coal, Mount Vernon (at the two last-mentioned localities pinnules of the so-called *Cyclopteris trichomanoides* also occurred); Bent Colliery, about 1½ mile E. of Bothwell; Pit near Coatbridge; Pit near Calder Iron-Works, Airdrie; Foxley, Shettleston; Calderbank, near Airdrie.

Neuropteris gigantea, Sternberg.

Neuropteris gigantea, Sternberg, Vers. i., fasc. iv., p. xvi.; Brongniart, Hist. d. végét. foss., p. 240, pl. lxix.

Osmunda gigantea, Sternberg, Vers. i., fasc. ii., pp. 33, 36, pl. xxii.

Remarks. The specimen from Coatbridge shows the fern in circinate vernation.

Localities. Bent Colliery, about 1½ mile E. of Bothwell; Coatbridge; Mount Vernon.

Neuropteris macrophylla, Brongniart.

Neuropteris macrophylla, Brongniart, Hist. d. végét. foss., p. 235, pl. lxv., fig. 1.

Osmunda, Scheuchzer, Herbarium diluvianum, p. 37, pl. x., fig. 3 (ed. 1709).

Remarks. The synonymy of this species is in a very unsatisfactory state; I therefore refrain from giving any further references.

Neuropteris macrophylla, which is one of the earliest figured ferns, occurs plentifully in some of the English Coal-fields; but the examples from Whiterigg are the first I have seen from a Scotch locality. Some of the specimens are very good, and show

attached to the main axis large cyclopteroid pinnules, analogous to those to which reference has already been made in regard to *Neuropteris heterophylla*, Brong.

Locality. Whiterigg Pit, near Airdrie.

ALETHOPTERIS, Sternberg.

Alethopteris lonchitica, Schlotheim, sp.

Alethopteris lonchitidis, Sternberg, Vers. i., fasc. iv., p. xxi.
Pecopteris lonchitica, Brongniart, Hist. d. végét. foss., p. 275, pl. lxxxiv.; Lindley & Hutton, Fossil Flora, vol. ii., pl. cliii.
Pecopteris heterophylla, Lindley & Hutton, Fossil Flora, vol. i., pl. xxxviii.

Remarks. This is one of the commonest ferns of the Scotch Coal-measures, and is subject to great variation. To many of these varieties specific names have been given.

Localities. Roof of Kiltongue Coal, Mount Vernon; Bent Colliery, about $1\frac{1}{2}$ mile E. of Bothwell; Whiterigg Colliery, near Airdrie; Foxley, Shettleston (and *var. Mantelli*); Calderbank, near Airdrie.

RHACOPHYLLUM, Schimper.

(?) *Rhacophyllum filiforme*, Gutbier, sp.

Fucoides filiformis, Gutbier, Vers. d. Zwickauer Schwarzkohlengebirges, p. 12, pl. i., fig. 9.

Remarks. Among the fossils is a small specimen of *Rhacophyllum* with filiform segments, which, though not very well preserved, is, I believe, referable to this species.

Locality. New Caledonian Railway Cutting, Airdrie.

LYCOPODIACEÆ.

LEPIDODENDRON, Sternberg.

Lepidodendron Sternbergii, Brongniart.

Lepidodendron Sternbergii, Brongniart, Prodrome, p. 85; Lindley & Hutton, Fossil Flora, vol. i., pl. iv., vol. ii., pl. cxii., vol. iii., pl. cciii.
Lepidodendron dichotomum, Sternberg (*in part*), Vers. i., fasc. i., pp. 19, 23, pls. i., ii. (excl. pl. iii.); and Vers. ii., p. 177, pl. lxviii., fig. 1.
Lepidodendron elegans, Hist. d. végét. foss. vol. ii., pl. xiv.;, Lindley & Hutton, Fossil Flora, vol. ii., pl. cxviii., vol. iii., pl. cxcix.
Lepidodendron gracile, Lindley & Hutton, Fossil Flora, vol. i., pl. ix.; Brongniart, Hist. d. végét. foss., vol. ii., pl. xv.
Lepidodendron lycopodioides, Sternberg, Vers. i., fasc. 2, p. 31, pl. xvi., figs. 1, 2, and 4.

Remarks. One or two very fine specimens of that form of *Lepidodendron Sternbergii* which has been named *L. lycopodioides*

by Sternberg and *L. elegans* by Brongniart were collected from a cutting on the new Caledonian Railway, near Airdrie.

Lepidodendron elegans and *L. gracile* appear to be only the younger and smaller branches of *Lepidodendron Sternbergii*, and not specifically distinct from that plant.

Localities. Cutting on new Caledonian Railway, Airdrie (*L. elegans*); Pit, Airdrie (*L. Sternbergii*); Bent Colliery, about $1\frac{1}{2}$ mile E. of Bothwell (*L. gracile*); Gartness, near Airdrie; Brownieside Pit, Plains, near Airdrie (*L. gracile*).

Lepidodendron aculeatum, Sternberg.

Lepidodendron aculeatum, Sternberg, Vers. 1, fasc. 1, pp. 20 and 23, pl. vi., fig. 2, pl. viii., fig. 1*b*; fasc. 2, p. 25, pl. xiv., figs. 1, 2, 3, 4, and fasc. 4, p. x.

Locality. Mount Vernon.

Lepidodendroid Branches.

Under this head I include two fine slabs from Whiterigg, which show on their surface a number of delicate twigs, measuring in some cases 10 or 11 inches in length, and about $\frac{1}{4}$ inch wide at their broadest part, including the leaves. The stems which bear the leaves are a little more than one tenth of an inch thick. The branches diminish gradually in width towards their apex. The leaves are very narrow, and about one fifth of an inch long. These two fossils are similar to those figured by Röhl as *Lycopodites selaginoides* ("Fossile Flora der Steinkohlen-Formation Westphalens," pl. vii., fig. 3).

I prefer, however, to record these specimens merely as Lepidodendroid twigs, rather than to place them under *Lycopodites*, for this genus, as founded by Brongniart, contained a number of Coniferous branches and small twigs of *Lepidodendron*, and was subsequently given up by that author; but *Lycopodites*, as resuscitated by Goldenberg,* contains certain plants very closely related to the recent genus *Lycopodium*, and quite distinct from *Lepidodendron*, and as the specimens from Whiterigg appear to be only young twigs of *Lepidodendron* (though of which species of *Lepidodendron* I am unable to say), they cannot be referred to *Lycopodites*, as restricted by Goldenberg.

* Goldenberg, "Flora Saræpontana fossilis," heft i., pp. 9, 10. 1855. See also Kidston, *Ann. & Mag. Nat. Hist.*, Aug. 1884, p. 111.

Locality. Blaes between Kiltongue and Drumgray Coals, Whiterigg, near Airdrie.

LEPIDOPHLOIOS, Sternberg.

Lepidophloios carinatus, Weiss.

Lepidophloios carinatus, Weiss, Foss. Flora d. jüng. Steink. w. d. Rothl. p. 155, Kidston, Catalogue of the Palæozoic Plants in the British Museum, p. 172. 1886.

Remarks. Several specimens of this species have been collected.

Localities. Pit near Coatbridge; and in debris taken from the foundation of the new Caledonian Railway Bridge, Calderbank.

LEPIDOPHYLLUM, Brongniart.

Lepidophyllum lanceolatum, Lindley & Hutton.

Lepidophyllum lanceolatum, Lindley & Hutton, Fossil Flora, vol. i., pl. vii., figs. 3, 4.

Remarks. In *Lepidophyllum* are placed isolated bracts and leaves, which apparently belong in part to *Lepidodendron*, *Lepidophloios*, and *Sigillaria*.

Localities. Pit, Airdrie. Bent Colliery, about $1\frac{1}{2}$ mile E. of Bothwell.

Lepidophyllum intermedium, Lindley & Hutton.

Lepidophyllum intermedium, Lindley & Hutton, Foss. Flora, vol. i., pl. xliii., fig. 3.

Locality. Calderbank, near Airdrie.

LEPIDOSTROBUS, Brongniart.

Lepidostrobus variabilis, Lindley & Hutton.

Lepidostrobus variabilis, Lindley & Hutton, Fossil Flora, vol. i., pls. x., xi.

Remarks. Under this name are most probably included the cones of different species of Lycopods.

Localities. Blackband, Airdrie; Bent Colliery, about $1\frac{1}{2}$ mile E. of Bothwell; Mount Vernon; Pit near Calder Iron Works, Airdrie.

Lepidostrobus, sp.

Localities. Mount Vernon; Pit near Calder Iron Works, Airdrie.

SIGILLARIA, Brongniart.

Sigillaria discophora, König, sp.

Lepidodendron discophorum, König, Icones fossilium sectiles, pl. xvi., fig. 194. 1825.

Ulodendron majus, Lindley & Hutton, Fossil Flora, vol. i., pl. v. (excl. ref.).

Ulodendron minus, Lindley & Hutton, Fossil Flora, vol. i., pl. vi. (excl. ref.).

Remarks. *Ulodendron minus*, L. & H., is only a smaller specimen of their *Ulodendron majus*, and both are similar to the plant described by König as *Lepidodendron discophorum*.

It is now known that certain *Ulodendra*, such as *U. parmatum*, Carruthers (= *U. commutatum*, Schimper), belong to *Lepidodendron Veltheimianum*, Sternberg, and there are other *Lepidodendra* which also bear Ulodendroid scars. But in addition to *Lepidodendra*, some Clathrarian *Sigillariæ* were likewise provided with Ulodendroid scars, of which *Sigillaria discophora* is an example. Ulodendroid scars also occur in the genus Bothrodendron, L. & H. (= *Rhytidodendron*, Boulay). The presence of these large scars cannot then be regarded as a generic character. The leaf-scars only afford the necessary comparative points for the classification of these so-called Ulodendroid Lycopods, and the leaf-scars of *Sigillaria discophora* are essentially those of a Clathrarian *Sigillaria*.

Localities. Pit near Airdrie; Toad Pit, near Airdrie.

Sigillaria notata, Steinhauer, sp.

Sigillaria notata, Brongniart, Hist. d. végét. foss., p. 449, pl. cliii., fig. 1.
Phytolithus notatus, Steinhauer, *Amer. Phil. Trans.*, vol. i., pl. vii., fig. 3.

Remarks. This collection contains only one small specimen of this species, with narrow ribs and proportionately small leaf-scars. The leaf-scars are more distinct than figured by Brongniart; but in this character the plant varies much.

Locality. Bent Colliery, about $1\frac{1}{2}$ mile E. of Bothwell.

Sigillaria, sp.

Remarks. I place here a small decorticated example of a *Sigillaria*, which, in the absence of the outer surface of the stem, does not afford sufficient characters for a specific identification. It is the *Sigillaria* (*Syringodendron*) *cyclostigma*, Brong. (Hist. d. végét, foss., pl. clxvi., fig. 3), of which, however, nothing more can be said than that it is a decorticated condition of a *Sigillaria*.

Locality. Baillieston.

Bothrodendron minutifolium, Boulay, sp.

Bothrodendron minutifolium, Zeiller, *Bull. Soc. Géol. de France*, 3e sér., vol. xiv., p. 176, pl. ix., figs. 1, 1*a*, 1*b*, and 1*c*. 1885.

Rhytidodendron minutifolium, Boulay, Le terrain houiller du nord de la France et ses végétaux fossiles, p. 39, pl. iii., figs. 1 and 1 bis. 1876.

Remarks. Till lately I regarded the genus *Bothrodendron*, Lindley & Hutton, as only founded on a decorticated condition of their *Ulodendron*, and in this view I was supported by many British botanists.

Zeiller, however, has shown that *Bothrodendron*, Lindley & Hutton, is a true genus, and at my request has kindly figured an authentic specimen of *Bothrodendron punctatum* from Newcastle (Zeiller, l.c., pl. viii., fig. 1), which was presented under that name by Dr. Hutton to the Museum d' Histoire Naturelle de Paris, in 1836. (Number in Museum Catalogue, 1367). It has been further shown that the genus *Rhytidodendron*, Boulay (in which I formerly placed *B. minutifolium*), is none other than *Bothrodendron*, Lindley & Hutton. It is a very remarkable circumstance that, though I have carefully searched, I have not yet discovered in Britain, either in museums or private collections, a single specimen of *Bothrodendron punctatum*, and, as far as can be ascertained, the Newcastle examples, of which there are three in the Museum of Nat. Hist., Paris, are the only British examples of this species extant. The plants, therefore, that I included under *Rhytidodendron* in my paper, "On the Relationship of *Ulodendron* to *Lepidodendron*, etc. (*Annals and Mag. Nat. Hist.*, 1885, p. 174) must be transferred to *Bothrodendron*, and also *Bothrodendron punctatum* must be removed from the synonymy of *Sigillaria discophora*, König, sp., and regarded as a true species (*Annals and Mag. Nat. Hist.*, l.c., 1885, p. 251).

At Calderbank some good specimens of *Bothrodendron minutifolium* were collected, a few showing the smaller branches with the foliage still attached.

Locality. Debris from foundation of new Caledonian Railway Bridge, Calderbank, about two miles south of Airdrie.

Lycopod Spores.

Remarks. These are probably the spores of *Lepidodendron* or *Sigillaria*. They are about $\frac{1}{25}$ inch in diameter, and apparently

belong to Reinsch's group Triletes.* These little spores almost entirely cover the surface of some small slabs, and are restricted to the "parting" of the stone.

Locality. Blaes at old pit, near Airdrie.

STIGMARIA, Brongniart.

Stigmaria ficoides, Brongniart.

Stigmaria ficoides, Brongniart, Class. d. végét. foss., p. 9, pl. i., fig. 7; Lindley & Hutton, Fossil Flora, vol. i., pls. xxxi.-vi.

Stigmaria ficoides (and vars.), Göppert, Gatt. d. foss. Pflanzen, lief. 1, 2, p. 13, pls. viii.-xvi.

Remarks. Stigmariæ, the roots of *Lepidodendron* and *Sigillaria*, are common throughout the whole of the Coal-measures. The specimen from Airdrie shows a transition from the Lepidodendroid leaf-scar to the Stigmarian root-scar. The Stigmarian vascular scar is here surrounded by a "field," similar to that which surrounds the vascular impression of the Lepidodendroid leaf-scar.

Stigmaria ficoides, var. *reticulata* (Göppert), has also been met with.

Localities. Common throughout the whole district. *Stigmaria ficoides*, var. *reticulata*, above oil-shales, Airdrie.

CYCADACEÆ.

CORDAITES, Unger.

The internal organization of the leaves, flowers, and stems of *Cordaites* has been fully described by Grand'Eury and Renault.† According to Grand'Eury, the stems of *Cordaites* attained a height of from 20 to over 30 feet, and were irregularly ramified. At the upper extremities of the branches and stems were borne the long narrow leaves. In *Cordaites* the pith was chambered, and the curious fossils, variously called *Sternbergia* or *Artisia*, are casts of its pith-cavity.

The wood in structure approaches closely to that of the Coniferæ, and was previously described as *Pinites Brandlingii* by Witham.

* "Micro-Palæo-Phytologia Formationis Carboniferæ," vol. i., p. 1, 1884. (Vols. i. and ii. Erlangen, Bavaria, 1884. Many hundreds of these organisms are figured in this work.)

† For a full description of the structure of *Cordaites*, see Renault, "Cours de botanique fossile," première année, Paris, 1881; Grand'Eury, "Flore carbonifère du Département de la Loire et du centre de la France," 1877; Zittel-Schenk, "Handbuch der Paläontologie," ii. band, lief. iii., p. 241, 1884.

It is also most probable that many of the fossil woods referred to *Pinites*, Witham (*Araucarioxylon*, Kraus; *Araucarites*, Göppert), are portions of the stems of *Cordaites*. The wood-fibres bear one or many vertical rows of bordered pits. The leaves are more or less long in proportion to their width; and from characters derived from these organs, Grand'Eury proposes for *Cordaites* the three following divisions:—

I. *Eucordaites.*—Leaves spathulate, obovate, elliptical, or lanceolate, sessile, entire, with rounded apices and of leathery consistency. The leaves are from 20–90 centim. in length. The nerves are either equally or unequally strong.

II. *Dorycordaites.*—Leaves lanceolate with sharp points; nerves numerous, fine, and equal in strength. The leaves attain a length of from 40–50 centim.

III. *Poacordaites.*—Leaves narrow, linear, entire, blunt at the point, with nerves nearly equally strong. The leaves are as much as 40 centim. in length.*

The flowers of *Cordaites* are monœcious. The male flowers consist of a number of imbricated bracts, in the axils of which are situated the stamens, or they are placed around the depressed apex of the axis of inflorescence. The female flower contains several naked ovules, which are short-stalked and set in the axils of the bracts. Their fertilization takes place in a somewhat similar manner to that of the Cycads and Conifers. During the maturation of the fruit the short stalk, to which the seed is attached, in some cases becomes much elongated, as in *Cardiocarpus* (*Cordaianthus*) *Lindleyi*, Carruthers, and *Cardiocarpus anomalus*, Morris, sp. In very few cases have the flowers been found in union with their parent stems, so till we know to which species of *Cordaites* the isolated inflorescences and fruits belong, it is necessary to apply to them specific names in order that their occurrence may be recorded. The structure of the seeds has been investigated by Brongniart.†

* Since writing the above a new type of *Cordaites* has been described by Renault and Zeiller, which they have named *Scutocordaites*, '*Comptes Rendus*,' March 23, 1885.

† Brongniart, "Recherches sur les graines fossiles silicifiées," Paris, 1881. Also, "Études sur les graines fossiles trouvées à l'état silicifié dans le terrain houiller de Saint Etienne," *Annales des Sciences Nat. botan.*, 5e sér., vol. xx., pls. xx.-xxiii.

From the results of the observations of those botanists who have been successful in securing specimens preserved in silica, in which the most minute details of structure are exhibited, even to the pollen-grains, it appears that *Cordaites* must be looked upon rather as a *group* of plants than a *genus*. In certain structural points *Cordaites* approaches closely to the Coniferæ, in other respects to the Cycads; but taking into account all the structural peculiarities of the plants, their affinities appear to be more Cycadaceous than Coniferous.

I have given but a meagre outline of the organization of these plants, and must refer those who are interested in the subject to the original works of the authors quoted.

From the fragmentary manner in which *Cordaites* usually occurs, the chief specific characters are derived from the nervation of the leaves.

Cordaites (*Eucordaites*) *principalis*, Germar, sp.

Cordaites principalis, Geinitz, Vers. d. Steinkf. in Sachsen, p. 41, pl. xxi., figs. 1-6 (excl. fig. 22).

Cordaites principalis, Weiss, Foss. Flora d. jüng. Stk. u. d. Rothl., p. 200.

Flabellaria principalis, Germar, Vers. v. Wettin. u. Löbejun, p. 55, pl. xxiii.

Pycnophyllum principale, Schimper, Traité de paléont. végét., vol. ii., p. 181.

Description. Leaves long, attaining a length of from 12 to 18 inches, and sometimes rather over 2 inches wide, narrowed towards the base and again narrowing towards the apex, the extreme point of which is rounded or obtuse; seven or eight of the stronger nerves in one tenth of an inch, between which are from three to five finer (?) nerves.

Remarks. In well-preserved specimens there are seen running parallel with and between the strong nerves from three to five fine lines. These are described by Geinitz as vertical rows of cells, and his fig. 2, pl. xxi., shows these finer lines strongly magnified, and certainly they here appear more like rows of tabular cells than veins; but Weiss, in his description of the species, calls them nerves. Only very perfectly preserved specimens can decide whether the finer lines placed between the strong nerves aré rows of cells or finer nerves.

The plant included here I have little doubt is Germar's species. It is very frequent in the Scotch Coal-fields.

Localities. Bent Colliery, about $1\frac{1}{2}$ mile E. of Bellshill; Pit near Calder Iron Works, Airdrie.

CARDIOCARPUS, Brongniart.

Cardiocarpus (*Cordaianthus*) *Lindleyi*, Carruthers.

Cardiocarpon Lindleyi, Carruthers, Notes on some Fossil Plants, figs. 1 and 2, *Geol. Mag.*, vol. ix., 1872.

Cardiocarpon acutum, Lindley & Hutton, Fossil Flora, vol. i., pl. lxxvi.

Cardiocarpon apiculatum, Berger & Göppert, Fruct. et. semin., p. 23, pl. ii., fig. 32.

Antholithes Pitcairniæ, Lindley & Hutton, Fossil Flora, vol. ii., pl. lxxxii.

Remarks. These little seeds have been found attached to stems, which were previously called *Antholithes Pitcairniæ*, Lindley & Hutton, by Mr. C. W. Peach, at the Cleuch, Falkirk, and have been described and figured by Mr. Carruthers in the *Geol. Mag.*, vol. ix., 1872.

As *Cardiocarpon Lindleyi* is almost invariably found associated with *Cordaites principalis* it is perhaps the fruit of that species.

Localities. Bent Colliery, Bellshill; Foxley, Shettleston.

CORDAIANTHUS, Grand'Eury.

Cordaianthus, sp.

Remarks. This specimen is probably a young condition of *Antholithes Pitcairniæ*, L. & H., and is the female inflorescence of a *Cordaites*. The fossil shows an axis $3\frac{1}{4}$ inches long, and at its basal extremity it is fully $\frac{1}{10}$ inch wide. On each side of the stem is a vertical row of alternate bracts, from the axils of some of which traces of fruit-pedicels can be seen. Each row contains about twenty groups of bracts; those at the base of the inflorescence are about $\frac{1}{5}$ inch long and rather less than $\frac{1}{10}$ inch wide; but they become slightly smaller and more distant towards the upper part of the specimen, of which, however, the extreme apex is wanting. The structure and number of bracts in each group is not shown. On the same slab is a specimen of *Cardiocarpus Lindleyi*. This example of *Cordaianthus* was found associated with *Cordaites principalis*, Germar, sp.

Locality. Bent Colliery, about $1\frac{1}{2}$ mile E. of Bothwell.

Cordaites Stems.

Notwithstanding the frequent occurrence of *Cordaites* leaves throughout the whole of the Scotch coal measures, extremely

seldom are any stems found. Mr. Dunlop has been successful in discovering two small specimens, both of which are well preserved.

Locality. Brownieside Pit, Mains, near Airdrie.

Of uncertain affinity.

TRIGONOCARPUS, Brongniart.

Trigonocarpus Parkinsoni, Brongniart.

Trigonocarpum Parkinsonis, Brongniart, Prodrome, p. 137.

Trigonocarpum Noeggerathii, Lindley & Hutton (not Sternberg), Fossil Flora, vol. ii., pl. cxlii. c; vol. iii., pl. cxciii., figs. 1-4 B, pl. ccxxii., figs. 2 and 4.

Remarks. Carpolithes alatus, Lindley & Hutton (Fossil Flora, vol. ii., pl. lxxxvii., vol. iii., pl. ccx. B), appears to be only *Trigonocarpus Parkinsoni* enclosed in its pericarp. It is not yet discovered to which plant these seeds belong.

Specimens of *Trigonocarpi* have been found in which the internal structure was preserved, and these show that it is Gymnospermous.

Localities. Roof of Kiltongue Coal, Mount Vernon; Pit near Coatbridge.

RHABDOCARPUS, Göppert & Berger.

Rhabdocarpus elongatus, n.s.

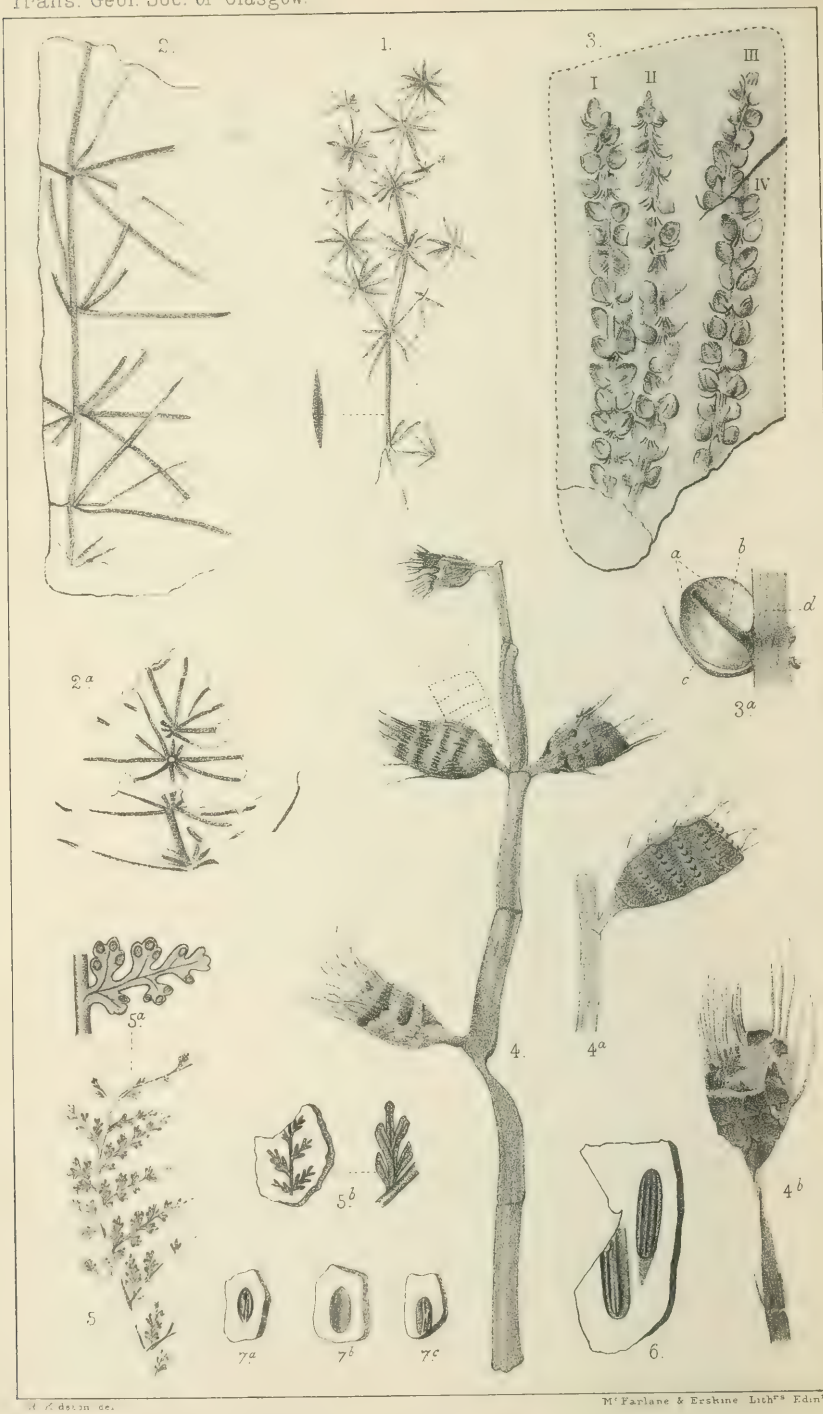
Pl. III., fig. 6.

Description. Seed narrow-oblong, rounded at the apex, and gradually contracting from the centre into a stalk-like pedicel. The exposed surface bears four longitudinal ridges.

Remarks. The figure shows a perfect specimen and portion of a second. From the position these two seeds hold to each other; they were probably attached to the same stem, but this cannot be determined.

Rhabdocarpus elongatus approaches very closely to *R. orientalis* as figured by Schmalhausen from the Lower Carboniferous of the Eastern Urals, (*Mem. de l'Acad. Impér. d. Sc. St. Pétersbourg*, vol. xxxi., no. 13, pl. iv., fig. 15), but is narrower in proportion to its length.

The more perfect specimen of *R. elongatus* figured on Pl. III., fig. 6, is 15 mm. long and 3 mm. wide. The specimens, however, vary slightly in size.



M'Farlane & Erskine Lith^rs Edin^r

CARBONIFEROUS FOSSIL PLANTS.

Locality. Debris taken from the foundation of the new Caledonian Railway Bridge, Calderbank, about three miles south of Airdrie.

CARPOLITHUS, Sternberg.

Carpolithus bivalvis, Göppert.

Pl. III., fig. 7.

Carpolithes bivalvis, Berger & Göppert. De fructibus et seminibus ex formatione lithanthracum, p. 26, pl. ii., figs. 30 and 31.

Description. Small oval bodies about 5 mm. long and 2 mm. broad. Outer surface smooth.

Remarks. The nature of these small fossils is somewhat obscure. It is probable they are sporangia.

Locality. Pit near Kirkwood.

EXPLANATION OF PLATE. III.

FIG. 1. Foliage of *Calamites ramosus* (*Annularia radiata*, Brong.). Fig. 1*a*. One of the leaflets magnified. Specimen from Airdrie.

FIG. 2. *Annularia patens*, Sauveur. From pit near Airdrie. 2*a*. *Annularia patens*, Sauveur. From Furnace Bank Colliery, Old Sauchie, near Alloa, Clackmannanshire.

FIG. 3. *Palæostachya gracillima*, Weiss. From Calderbank, near Airdrie. Fig. 3*a*. Enlargement of portion of verticil showing *sporangium* (*a*) with its sporangiophore (*b*), sitting in the axil of the bract (*c*), axis of cone (*d*).

FIG. 4. (?) *Calamostachya longifolia*, Weiss. From Calderbank, near Airdrie. Figs. 4*a* and 4*b*. Two other isolated cones.

FIG. 5. (?) *Sphenopteris Schützei*, Stur. From Calderbank, near Airdrie. Fig. 5. Fertile portion. Fig. 5*a*. Fertile pinnule enlarged. Fig. 5*b*. Small fragment of barren condition.

FIG. 6. *Rhabdocarpus elongatus*, Kidston, n.s. From Calderbank, near Airdrie.

FIG. 7. *Carpolithus bivalvis*, Göppert. From pit near Kirkwood. Natural size.

No. V.—The Joint Excursion of the Edinburgh and Glasgow Geological Societies to Ben Nevis and the Parallel Roads of Lochaber, in July, 1885. By William Jolly, F.R.S.E., F.G.S., Leader of the Excursion.

[Read 12th November, 1885.]

Introduction.—On the 7th of May, 1885, I delivered an expository lecture before the Edinburgh Geological Society, and repeated the same on the 14th before this society, on "The Parallel Roads of Glen Roy: the Problem, its Conditions, and Solutions."* One result of these papers was that a joint excursion of members of both societies was arranged for Lochaber, to examine the problem on the spot, under the leadership of the lecturer. The excursion took place during the last week of July, from Monday, July 27th, to Saturday the 31st. The party numbered seventeen in all, of whom six were connected with the Edinburgh Society and nine with the Glasgow Society, another being a gentleman from Dorset, and the last Mr. Colin Livingstone, head master of the Public School of Fort-William, whose knowledge of the district and of the special subject is unrivalled, and whose services were of the greatest value to the party, as duly and heartily acknowledged. The whole cost of the excursion to each man was, on an average, about £5. The weather was superb, without a single shower; the sky cloudless and the air uncommonly clear, exhibiting the glorious scenery and the various phenomena to the best advantage; the party delightfully varied, bright and genial; and the whole experiences unusually pleasant, instructive, and memorable.

The time at disposal did not and could not allow of detailed investigation of the numerous and difficult points involved, scattered, as these are, over a broad mountainous district, and necessitating, as they undoubtedly do, the patient and minute observation of years, to be adequately mastered. All that could be attempted was to obtain a general idea of the numerous conditions of the problem, as exhibited on the spot, to see the wide and varied mountains and glens where they occur, and to examine somewhat more carefully some of the chief phenomena that require explana-

* See page 40.

tion; in order not so much to come to a decision then and there, as to enable the inquirers the better to comprehend the abundant literature on the subject, more intelligently to criticise the theories advanced, and finally help them to arrive at the most probable, if not the true, solution of this difficult and ever fascinating subject.

The present paper is intended to give a short account of the scientific side of the excursion only, leaving out the delightful scenic and social elements, which were not more pleasant than profitable, and which give to such excursions the rare union of intellect and feeling that makes them so delightful. The party found in Lochaber, as we all have pleasantly experienced elsewhere, that sociality may be united with science, and that even geology is no enemy to jollity.

I. BEN NEVIS.—*Monday, May 27th.*

1. From Oban to Fort-William.—The most of the party met at Oban, the Edinburgh members reaching it by steamer, and the Glasgow by rail. There we visited the marked junction of the Conglomerate with the underlying nearly vertical Silurian slates, on the shore between Oban and Dunolly Castle, and the striking rocky stack, known as the Dog Stone, to which Fingal used to tie his huge hound, and which is an isolated mass of the Conglomerate of the ancient Lake Lorne of Old Red times; exhibiting, at a glance, its various constituents. During the voyage to Fort-William, the geology of the coast and surrounding country claimed attention—the trap region behind Oban, the age of which still requires final determination; the rounded granite outburst of Ben Cruachan, of which Loch Etive occupies the centre; the limestone of Lismore and Appin; the clearly marked "ancient sea margins," everywhere apparent along the shore, in flat continuous terraces, steep cliffs, old sea caves and rock arches now inland, excavated by the old waves; and the evidences of glaciation in *roches moutonnées* on sea and land, in the flowing outlines of the mountains, in moraine matter, and in the scratched and polished surfaces of the bare rocks we passed. The party was specially struck with the geological features seen at the entrance of Loch Leven, the syenite mass of Scuir Donuil above the pier, the limestones and marbles on both sides of the loch, the slates of Ballachulish; and the severe glacial action to which the whole has been subjected at this narrow

outlet for the combined glaciers of Loch Leven and Glencoe, in remarkable striated surfaces easily noted from the steamer, and in the rubbed and smoothed outline of the well-named Scuir na Ciche, the Scuir of the Pap, set at the point between these two glens, whose graceful outlines were formed by the joint action of the glaciers that filled them and united below its front; the notable deposits of debris that form the peninsula of Corran or the Sickle, so named from its northern curve, a collection of soft materials which ought, at first sight, to have been swept away by the rapid currents that here rush through the Narrows, but which truly owe their preservation to these currents; and the schists and other rocks that form the straight and steep walls of Loch Eil north to Fort-William.

2. The Ascent.—The peak of Ben Nevis caught the eye shortly after leaving Loch Etive, and grew in massiveness and grandeur as we steamed northwards, clear to the summit. The unusual fineness of the weather naturally suggested the climbing of the big Ben that evening, and the idea was enthusiastically adopted and at once acted upon. After landing, Mr. Omond, the keeper of the summit observatory, and Fellow of the Edinburgh Society, who had been previously communicated with, was at once wired that he might look for us that night. The requisite arrangements having been quickly made, our waiting carriages carried us to the bridge of Nevis, where we began the ascent. Eleven of us took the hill—one on horseback, the rest on foot—and we all, with one exception, reached the top. The climbing took between four and five hours, and the last of the party, your humble servant, who, as whipper-in, had to bring up the rear, arrived at the Observatory a little after midnight. Though greatly favoured by the new, well-made and well-engineered path, which begins at the farm of Achintee, under the steep front of Meall-an-t-Suidhe, and which is four miles long, the ascent is still trying enough. It is, however, very much easier than it was, and it was manfully and smartly accomplished by the elders of the party, who took natural rests at intervals, of course, with the usual excuse of a desire the better to admire the scenery and examine the geology!

3. The Glen Nevis Glacier.—The lateral moraines of the Glen Nevis glacier are very well seen on both sides of the lower part of the glen, at different levels, curving round outwards along the western face of Meall-an-t-Suidhe, where the glacier, gradually

expanding from its narrow bounds in the steep Glen Nevis, spread outwards on the flat moorland of the Great Glen. As pointed out by Jamieson, these rubbish mounds show no trace of water action by sea or lake, and must, therefore, have been deposited after the great depression of the land, in the middle of the Glacier Period, to the probable depth of some 2,000 feet, and during the latter part of this period, when the land had greatly reached its present level. If this had not been the case, the moraine debris would have shown more or less powerful traces of re-sorting by the waves, especially in such a narrow glen, with a summit level of only 1,217 feet, through which a strong current would stream east and west. These moraines are very well seen from the mountain road, as they appear on the south side of the glen, above Glen Nevis House, where they lie in continuous lines, at successive levels, as left by the shrinking ice.

The detritus on the side of the glen next Ben Nevis is so abundant, and rock surfaces are so comparatively rare, that ice scratchings are not often seen during the ascent. At several places, however, they are very good, especially on the slates and chloritic schists near the mouth; for the granite of the greater part of the journey, disintegrating easily, does not preserve striations well, though showing creditably general smoothing and stoss and lee sides. All scratches run parallel to the glen, and prove the movement of a great glacier, some 2,000 feet in depth at its greatest dimensions, which gradually shrunk into nothingness, and at its later stages deposited the heaped moraines that cover the lower parts of the valley. There they could more easily rest than on its higher very steep or precipitous sides.

4. The Geological Structure of Ben Nevis.—The rocks at the mouth of Glen Nevis can be very well observed in the bed of the river, at different points on the path, dipping at a high angle to the S.E. They consist of a series of schists, mostly chloritic, with beds of quartzose rocks, calcareous shales, and the slates of Ballachulish. Whether these are all Silurian, as mapped by Archibald Geikie, or Pre-Cambrian covered by Silurian, as contested for by Dr. Hicks, it is beside our present purpose to inquire. On the south side of the glen, the sedimentary rocks are continuous, and are cut through by intrusive porphyries, but they contain little granite. None of the limestone is seen here, though it appears so largely in the rocky ridge of Donie, a little to the north,

at Blarmacfoldack, in the next glen to the south, and at Ballachulish—being worked at all these points.

The thick-bedded white Quartzite is similar in appearance and age to that which forms such a striking feature of the scenery at the head of Loch Maree, and at other parts of the N.W. coast, and has a large development in the upper reaches of the glen, especially on the south side. There it is seen to cap the chloritic series with the same S.E. dip; and it is itself overlaid by other slates and shales. Here, as everywhere else, it imparts grand and special characteristics to the scene. It forms the precipitous peaks of several of the highest summits, all above 3,000 feet, which form the magnificent mountain wall of Glen Nevis. Gleaming white, bare, and utterly barren, and often dazzling in the bright sunlight, it forcibly recalls some of the wild scenery of the West Coast, in which the chief element is the same or a similar Quartzite. This Quartzite, disintegrating easily, forms, in many cases, at Glen Nevis, rounded cones more or less pointed, called here from their shape *Stob*, a Gaelic word meaning a pin or point, and *Maim* or *Mam*, a word connected with the Latin *mamma*, a breast—both words aptly describing the form of the peaks. The adjective "Bahn," white, occurs frequently in the names of these hills, which are so called from the white Quartzite of their tops; as in Stob Bahn, 3,274 feet, immediately opposite Ben Nevis to the south, and another Stob Bahn, 3,217 feet, to the north of the summit level of Glen Nevis.

The new mountain path, which cost £1,800 to form, instead of following the old track past the distillery, along the *north* side of Meall-an-t-Suidhe, and thence between the lake and the Ben, takes the south side of the Meall, next Glen Nevis. It goes up the west side of the corry drained by the Alt na Urchaire, till it overlooks the lake on the south, and then winds over the broad shoulders of the mountain to the summit. Before the lake comes in view, it runs entirely over the slaty schists and their associated rocks, of which the Meall greatly consists. Beyond that, the igneous rocks that form the imperishable heart of Ben Nevis are soon entered on. These consist of a core of hardest porphyry—of different hues, but mostly dark—which forms the magnificent precipice of the Ben, some 1,500 feet sheer, and which faces Corry Lees to the north. This porphyry is surrounded on all sides, except at the precipice, by granite, both white and red, much, if not most, of the granite being syenitic. Both the porphyry and the granite have probably been

intruded through the sedimentary schists, slates, and quartzites which enclose it on all sides. These continue to dip to the S.E., and, as put by Dr. Hicks, are tilted up at an unusually high angle, and stand apparently end-ways against the base of Ben Nevis.*

The red granite or syenite gives name to the mountains which immediately surround the porphyry peak of the Ben itself, the adjective Dearg meaning red,—Carn Dearg, 3,961 feet to the N.W. of the highest point, and another of the same name (3,348 feet) to the S.S.W., while the long mountain ridge on the north side of Corry Lees bears the same epithet, with three peaks—More, the Great Cairn (3,950 feet), Meadhonach, or the Middle Cairn (3,873 feet), and Beg, or the Little Cairn (3,264 feet). In this way, the porphyry heart of the Ben is enclosed on all sides by a granitic envelope, which rise into five mighty peaks, only a little lower than itself, all bearing the same descriptive title of Dearg or Red.† These form, in reality, one unbroken mighty mountain mass, in the middle of which has been scooped out the huge, wild hollow of Corry Lees, in front of the great precipice of the central dome. Besides this red granite, there is also a large development of a grey variety, which is well seen where it is crossed on the way to the top.

5. The Ben Nevis Observatory.—The night was balmy and clear, and showed the gradually darkening landscape, in varied and telling lights, with admirable effect. The moon was then at full, and on these upper heights looked beautifully bright, and more like the burnished silver mirror of southern latitudes than the leaden luminary of our misty land. It hung in the blue east, and was hidden from view for most of the time by the intervening mountain mass, as we climbed its western front. The shadow of the Ben, thrown on the back of Meall-an-t-Suidhe with a clearness of outline scarcely credible, was a singular and uncommon sight. At various points, we emerged into the moon's bright light, which only intensified the black shadows into which we dropped, and the moon did not rise permanently till we reached the highest flat of the hill.

The toilsomeness of the ascent is much increased by the broken

* *Proceedings of the Geologists' Association*, vol. vii., No. 1.

† In other parts of the Ben Nevis mountains, the appellation Dearg or red indicates the presence of a red porphyry, which is abundantly developed in the range.

granite chips that compose the most of the path, all soil being quite washed out of it by the heavy rains and rapid runnels. The whole of the plateau at the summit consists of a layer of the same broken granite, porphyry and agglomerate, which shows a packed appearance, due no doubt to the pressure of the heavy snow field of the long-drawn winter. We were welcomed heartily and pleasantly by Mr. Omond and one of his assistants, the other being in bed; Mr. Omond himself always taking the night watch. The small but cozy reception room of the Observatory, crowded with our party, was a sight of rare picturesqueness at that midnight hour. As we sat round the warm stove, illuminated by the streaming lamp, cheered by the excellent tea, coffee, and abundant provision, and enlivened by much genial talk and high spirits, we looked, for all the world (especially with the somewhat exhausted condition of some of the members), like a crew of shipwrecked passengers from a wandering balloon in the coming years, stranded here and entertained by the kindly inmates of a lighthouse set in mid air.

6. The View from the Summit.—Before daybreak, we emerged from our comfortable cabin to examine the rocky islet on which we stood, this fancy being made the more real by the weird grey light that showed only our bare surroundings. The sight soon revealed by the slowly rising sun was wonderful, and impressive beyond description. The morning was clear to the farthest horizon. All around, especially to the south and east, stretched a rolling level ocean of unbroken white fleecy clouds, through which rose at intervals the peaks of the higher mountains, and beneath which, entirely hidden from view, lay the whole sleeping world. It was a vivid presentation of the aspect of the palæocrystic sea covered with a packed ice-floe, without a single berg; or it was a realization, to the eye, of the frozen sea in the middle of the last Glacial period, when the ocean stood two thousand feet above its present level, swathing all in ice, except the higher mountain tops, and enveloping the very mountain region on which we then looked down, while the whole glacial landscape was illuminated by the cold sun of the Arctic summer. The view stretched from Schiehallion on the east to the Uists on the west; Hecla in South Uist and the peaks of Harris being most distinct, away beyond the Isle of Skye and the serrated Coolins. It was such an expanse of view, seen under cloudless conditions, as is rare amid the western wet-

ness, and such as I had never had before among my many clamberings on these mountains; and this was my third visit to the top. The fleecy sea, gradually melting away, revealed the more substantial ocean of glen and mountain which heaved its billowy crests round this central peak.

The view of Glen Nevis from the edge of the southern Carn Dearg was remarkable in the pearly grey light, as you looked right down into its profound gorge and its numerous lateral corries—the extensive nursing ground of the old glaciers that concentrated in the narrow glen and crushed their resistless way out of its mouth at Loch Eil, down Loch Treig, and south to Loch Leven and the Moor of Rannoch.

7. The Aspect of the Top.—Deep snow wreaths lay in the protected hollows of the wide stony plateau, and clustered to a great depth, hard and firm, round the edge of the mighty precipice. There, at the very end of July, we made snowballs, and threw them at each other like school boys, our hearts being then as light as in the early days. Several of the younger members sent great rocks plunging down the precipice, which were at once lost to view in the gloom, but sounded their thunderous way, to join the blocks that form the enormous talus of the cliff, detached by the frosts of ten thousand years.

After accompanying Mr. Omond in his visit to the various instruments; inspecting the Observatory and its interesting contents, and the new turret erected to overtop the snows of winter which bury the house itself; sending off messages to our distant friends, and partaking of an early breakfast—we parted with our kindly hosts with heartiest thanks and loud parting cheers. The wooden hotel on the summit, crowded with visitors, was silent and shut at our midnight arrival, and as we left, its inmates began to crawl forth in the chill air.

8. The Descent.—In the bright morning, we were able to examine the rocks more carefully than in the dimness of the previous night, and to observe more clearly the surrounding country, with its splendid combinations of sea and land, mountain and glen, moor and stream. The green hollow crest of the vitrified fort of Dundbhairdghall, or Dungardil, on the other side of the Glen, was well seen; as well as the valley beyond it, down which a branch of the Glen Nevis glacier once went, when the ice rose higher than 900 feet, the level of the pass at the fort.

9. The Drive to Roy Bridge.—Joining our carriages a little after eight o'clock, on Tuesday the 28th, we drove towards Roy Bridge. On the left, we looked down on an old bed of the River Spean, where nestles the farm of Auchindaul, before it cuts its way through the narrow, rocky gorge at High Bridge, on General Wade's old road. To the right, stretched the moory ridge of Unachan, which figures so much in Glen Roy literature, as the remains of a possible dam to the old lake. On the way, we crossed those strange, kaim-like lines of debris which traverse Unachan in succession, and run across the high road, and up the opposite ridge of Meal Dhu ; some of them onwards over the Spean to the slopes of Stron-a-baa, overlooking Loch Lochy. These are doubtless connected with the glaciation of the district, but they have not received sufficient attention in relation to this subject.*

II. GLEN ROY.—*Tuesday, July 28th.*

Having reached our inn at Roy Bridge, secured quarters for the whole company, and substantially breakfasted, we set out for the head of Glen Roy to examine the famous "Roads" or "Parallels," the main object of our journey, which have attracted the study of our foremost geologists, raised more controversy, and created more extensive literature, than perhaps any other single geological problem.

1. The View from Bohuntine Hill.—After catching various glimpses of them, especially when opposite Glen Glaster, we reached the famous point of view on the north side of Bohuntine Hill, above Achavaddy, where the greater part of Glen Roy stretches right before the spectator. There the strange triple lines are seen, traced upon its bare, treeless, grassy sides, with marvellous and indelible distinctness—a sight once seen never to be forgotten, and certainly, of its kind, unsurpassed, if not unique, on the surface of our globe. The Roads remain ever wonderful, even to those who have often seen them. They are much less distinct in the *mid-day* light than at morning or evening, when the slanting rays, deepening the shadows, greatly increase their clearness. While the party were seated there, gazing on the impressive scene, the author gave an exposition of the character of the Roads,

* A paper on these lines appears in the *Transactions* of the Inverness Field Club, Vol. I., by Mr. Colin Livingstone, of Fort-William.

the conditions of the problem, and the various theories propounded to explain them, in the lines of the exposition given in May last.*

2. The Head of the Glen.—This finished, we continued our journey to the head of the Glen, at the junction of the Turret and the Roy. From the central flat plain of gravelly debris, between these rivers, the level of which is a little below that of the lowest "Parallel," you have the whole of the Roads exhibited round you on every side, more distinctly than at any other point. On Carn Dearg (Jamieson's "Tom Brahn"), situated between the Turret and the Roy, they are remarkably clear, being the best in all these Glens, especially just above Lechroy, where they are as broad and plain as a railway embankment. These were, however, too distant to be reached in the time. Some of us climbed to No. IV. (as the lowest Road is known in the literature of the subject), at a part distinct when viewed at a distance, but difficult to make out on the hillside when reached—a common experience where the slope is not steep, and where the Road blends more or less with the face of the hill.

The upper reaches of Glen Roy are here well seen, where Nos. IV. and III. unite from opposite sides of the valley; while No. II. or the highest, disappears through the col that leads over the watershed to Lochan Spey, a few miles off, the head waters of that river. This col formed the outlet of the Glen Roy lake when it stood at its highest level, which thus discharged its waters into the German Ocean by Strathspey.

Through this pass also, and down Strathspey, flowed the great stream of ice that filled Glen Roy during the Glacial Period; but, prior to the formation of these Roads, when Glen Roy formed one outflow to the immense accumulation of glacier ice that blocked Glen Spean. This is a passage for the ice at first sight unexpected and surprising; but it is incontestably proved by the striations, *roches moutonnées*, and their well-marked stoss and lee sides, at the head of Glen Roy—as acknowledged by Jamieson and other observers, and examined and marked in detail by myself.

In the opposite direction, towards the S.W., you look through another pass, drained by a small stream called Alt a' Chomblain,† the summit level of which is 1,172 feet. Through this came the overflow of the lake that filled Glen Gluoy. There a similar

* See the substance of this exposition in the present volume, p. 40.

† Wrongly called Glen Turrit in Jamieson's Map.

Road exists, known from its height as No. I., 1,173 feet; as well as traces of others at lower levels, but all higher than the highest in Glen Roy (No. II.),which stands at an average of 1,148 feet; No. III. being 81 feet and No. IV. 212 feet lower still. Glen Gluoy lake thus formed a tributary to that of Glen Roy, being dammed back by a sufficient barrier at its mouth, opposite Loch Arkaig. Through this pass came also the ice stream that was forced up Glen Gluoy, and out into Glen Roy before the Glen Gluoy lake was formed.*

Had the vigour of the party not been largely drained by the sleepless night on Ben Nevis, much more would have been done and seen at this most interesting centre of observation and inquiry; for many phenomena there exhibited claim careful examination, and have not received the attention they deserve even from writers on the subject.

3. The Return Journey showed the Roads with greater distinctness in the evening shadows, especially on the steep sides of Ben Iaruinn. The curving round of Nos. II. and III. into and through "the Gap" above Achavaddy, between Bohuntine Hill and Leana More, was well seen. The deep debris which clothes the whole of the mountains of Lochaber, and especially of Glen Roy, upon which the Roads have been impressed, was well exhibited in numerous sections cut through by the rapid and powerful streams that descend the steep sides of the Glen and cross the high road we traversed. The abundant fine gravelly deposits that have accumulated between Bohuntine Hill and Meall Dhu, above Cranachan, below the level of No. IV.—deposits in the bottom of the ancient Glen Roy lake—also claimed attention. The sudden termination of the "Parallels" at points symmetrically opposite each other on both sides of the Glen, without any cause apparent to the eye, such as heaped debris, was remarked as an important item requiring explanation in any theory advanced for their solution.

A comfortable meal and the profound sleep of the weary and the just ended our first double day's delightful experiences.

* See present vol., p. 46.

III.—GLEN SPEAN AND LOCH TREIG.—

Wednesday, July 29th.

1. The Valley of the Spean.—Next morning, accompanied by more of our Edinburgh friends who had arrived the night before, we set out to examine the upper parts of Glen Spean and its tributary streams. The lowest "Parallel," No. IV., extends up this strath as far as Loch Laggan. This lake is, in truth, an existing representative of the ancient lake that had carved these lines on the mountain sides! The two higher "Parallels" terminate at the mouth of Glen Roy itself, on both sides of Bohuntine Hill and on the mountains opposite.

The morning was bright, the scenery splendid, and our spirits were correspondingly elevated. No. IV. was at once distinctly visible on the opposite side of the valley, running along the steep face of Ben Chlinaig and extending seawards to its own termination at Corrie Choilzie. It soon appeared with great clearness on the north side of the glen, on the front of Craig Dhu, round which it sweeps into Glen Roy, and it curved up the strath before us to the left on to the summit level at Roughburn.

2. Chambers' Other "Parallels."— Other lines were observed both above and below No. IV., especially on Craig Dhu. These were interesting as being those on which Robert Chambers based his argument, in the "Ancient Sea Margins," in favour of the marine origin of the "Parallels." His reasoning may be thus put:—Lines the same in kind with the so-called "Parallels" incontestibly exist both above and below the "Parallels," down to the lower levels, as well as abundant gravelly deposits in the bottom of the glen, which can be proved to be laid down by the sea. Similar lines are found all over the country, which he contended are all "ancient sea margins," and which he laboriously catalogued. If these numerous other lines are laid down by the sea, the similar "Parallels" of Lochaber have been formed in the same manner. These are, therefore, simply very distinct sea beaches.

The argument was ingenious and looked logical. It seemed to be supported by a mass of wide-spread evidence, which required a large volume to detail it. It would have been conclusive, if the *similarity in kind* between the "Parallels" and the other lines in Lochaber and elsewhere, on which the whole arrangement rested, had been borne out by facts. But, unfortunately, the other lines in

Lochaber, so carefully registered by Chambers, are found, on examination, to differ entirely from the "Parallels" in outline, formation, breadth, relation to the mountain sides, extent, and other characteristics. They were, therefore, produced by entirely different causes, as the author endeavoured to prove in a paper read before the Edinburgh Geological Society on the 17th of April, 1873, which appears in abstract in the *Transactions*.* There it is contended that these other lines are lateral moraines, marking the successive boundaries of the glacial ice that filled Glen Spean, an opinion briefly indicated by Jamieson: whereas the famous "Parallels," according to most observers, are proved, by outline, slope, equality of breadth, composition, and otherwise, to be deposited by water; while certain lower stratified terraces in Glen Spean, on the other hand, are admittedly laid down or re-sorted by the waters of sea, or lake, or both. This lower-terraced detritus is seen abundantly exhibited all along the bottom of Glen Spean, and in striking amount near Murlaggan.

The existence of a series of former lakes along the Spean was evidenced at different levels, especially on the flat above the rocky barrier that forms the falls of the Spean, called Eas na Smuid, or the Fall of Smoke, near Spean Lodge. Here the waters of the Spean must have been barred back into a lake, before they cut the difficult track through the present narrow rocky canal that exists at the falls. A similar lake evidently existed above this, opposite Tulloch. The presence of such lakes is noted by Milne Home in his valuable and elaborate papers on Glen Roy, in the *Transactions* of the Edinburgh Royal Society for 1846 and 1847. The character of both classes of lines, which Chambers thus failed to discriminate (viz., the "Parallels" and the ridgy moraines), and their relations to each other, are very well shown on the front of Craig Choinnichte, which is the eastern continuation of Craig Dhu, opposite Tulloch and Inverlaire. There they are mingled together, and can be easily examined a short distance above the highway; both lines running on more or less continuously, but very different in character, along the face of Craig Dhu.

3. Glacial Phenomena in Glen Spean.—The carried blocks, which are so numerous in this valley, especially on Craig Dhu,

* "Notes on the Glaciers of Glen Spean and their relations to Glen Roy." See also fuller quotations from the paper in Milne Home's paper in *Trans. of Royal Soc. Edin.*, vol. xxvii., 1876.

were also noted, up to its peaked summit, 2,161 feet. Clach Mhor, or the Big Stone, which consists of grey syenite, weighs 40 tons, and stands only a little below its top, was distinctly visible on the sky line; its original site, as well as that of the numerous granite blocks scattered over this and other hills, being still undetermined.*

Glaciated rock surfaces were examined at various points on the floor of Glen Spean, where they are exceedingly well exhibited all along the valley, from Glen Roy on by Loch Laggan to Kingussie. We drove to the rocky projection on the road, just west of Roughburn, where it overhangs the Spean. There occur the best ice scratches along the whole route. These are beautifully, and it is to be hoped imperishably, traced on the fine-grained grey syenite, so largely developed opposite Loch Treig.

In the lower parts of Glen Spean, the scratches run parallel to the general trend of the valley; in the upper, they gradually begin to curve southwards towards the mouth of Loch Treig; opposite it, they point directly southwards into its opening; beyond that, they curve towards the N.E., still, however, pointing towards Loch Treig; till at length they once more run parallel to the line of Loch Laggan. Along its shores, at various places, they are finely shown, especially at the roadside beyond Moy, near the painter Ansdell's house. These parallel directions and systematic deflections from the main run of the valley of the Spean, combined with other considerations too long here to state, seem decidedly to prove the existence of a glacier protruding from the close mountainous glen of Loch Treig, fed, as it would be, by an extensive ice-generating area at the back of the Nevis mountains. Such is the opinion of Jamieson and most other observers, except Milne Home. Filled with growing opposition to local glaciation, and an admiration of his great North-West Arctic current, with its floating and scratching bergs, he contends that the glaciation of the Spean was made by floating ice borne *upwards* along the valley from the west. In this contention, so far as I am aware, he stands quite alone. But this is not the place to enter into the polemics of the subject, in which a single redoubtable champion

* For notes on these blocks, see the Reports of the Boulder Committee of the Edinburgh Royal Society, of which Milne Home was the indefatigable convener.

stands undismayed on the one side, against a host, not less fearless and firm, on the other.*

4. The Great Horse-shoe Moraines of the Treig Glacier.—We ascended to the top of the syenite ridge above Roughburn, which is the centre of the broad undulating plain into which Glen Spean there widens, five miles in breadth from Loch Treig across to Ben a'Mheirlich on the north side of the strath. The view from this point was expansive and magnificent, unsurpassed of its kind in the country. Before us stretched the splendid series of giant peaks, most of them over 3,000 feet, from Ben Alder to Ben Nevis—at once the highest, wildest, and grandest in Britain. Right in front of us, the range was deeply and sharply cleft in twain by a steep, narrow gorge, in which lies embosomed the dark and deep Loch Treig, whose waters were seen gleaming in the morning sun; this loch being one of the finest and most picturesque of our wilder and more secluded mountain lakes.† Running straight into the mouth of Loch Treig, the lowest "Parallel" was beautifully seen impressed upon the hills on both sides, a little above the surface of the water. Below us, across the Spean, expanded the great moory undulating flat, called Sliabh Lorgach.

Extending from the left side of the mouth of Loch Treig, a series of ridgy lines was distinctly traceable at a height of near 1,500 feet, nearly half way up the face of Garbh Beinn, which forms the eastern wall of Glen Treig. These ran onwards to Craig Dhu of Fersit, curved continuously in successive ramparts across Sliabh Lorgach on to Roughburn, where they passed the Spean at 800 feet, and swept round to the north, behind us, uninterruptedly onwards to the front of lower Craig Dhu, where they united again with the lowest "Parallel."

These ridges form what most glacialists who have examined them consider to be the successive moraine boundaries of the great glacier which here projected across the valley of the Spean from the basin of Loch Treig. These were first brought under notice by Jamieson in his well-known paper on Glen Roy, published in

* See Milne Home's papers on Glen Roy in *Transactions of Edin. Royal Soc.* for 1876 and 1877, and the Reports of their Boulder Committee.

† See this view admirably rendered by Captain White in Sir Henry James's "Parallel Roads of Lochaber," published by the Ordnance Survey, as well as other views in Glen Roy and Glen Spean—a book worth possessing for these views alone.

1863, and were more fully described by the author in the paper already mentioned on "The Glaciers of Glen Spean," read in 1873; in another paper read before the Inverness Field Club in 1880*; and again in 1885 before the Edinburgh and Glasgow Geological Societies, which led to the excursion now described. The author is now engaged on a full treatment of them in a paper which he hopes soon to read before the Royal Society of Edinburgh on the "Glaciation of the Nevis Mountains."

On the other hand, Milne Home firmly holds that they are not moraines at all, but the kaims of "submarine detritus, which have been scoured out into long banks by the action of sea currents." He nevertheless acknowledges "that they deserve much more examination" than he had the power of giving. He is also obliged to concede that "a small glacier existed in Glen Treig, and that it even probably protruded a little way into the valley." †

Into this controversy we cannot here enter. I simply express my belief, after nearly twenty years of examination, that they are the moraines left during the last stages of the glacier of the Treig, before it shrunk back into the mouth of the deep hollow of Glen Treig, and thus allowed the waters of the lowest Road to stretch on to the pass of Makoul at the eastern extremity of Loch Laggan. There they had their outlet, and so ran eastwards down Strathspey into the German Ocean, into which the waters of the three ancient Lochaber lakes all flowed.

In order to examine these curving ridges and see the whole from the best point of vantage, we ascended to the end of Craig Choinnichte. There they impinge on its eastern slopes, and continue along the front of Craig Dhu, some distance above No. IV. "Parallel." From this elevation, the moraines presented a splendid appearance, sweeping round from the mouth of Glen Treig, across Sliabh Lorgach, over the Spean, and onwards to where we stood, in magnificent curves, some four miles in diameter; and they greatly impressed our party. They consist of several concentric lines, two of which are more or less continuous, the outmost lines being fragmentary. The outer of the two great and more distinct circles has a general resemblance to a kaim, being composed of debris of varying roughness, embodying blocks of different

* See the *Transactions* of the Club, Vol. I.; *Nature* for May 20, 1880; and the present Vol., p. 40.

† See the tenth and last Report of the Boulder Committee, p. 151.

sizes, and having an undulating outline. The inner circle consists of a *traineé* of blocks of all sizes, chiefly of grey syenite. These ridges vary in height from 10 to 30 feet, and their composition is easily examined at the place where we stood, at which the outer and inner greater circles unite. Inside these curves, numberless blocks are scattered about, of all sizes, from mere stones to rocks, many of which are thirty feet high.

On the way to our carriages, we crossed "Parallel" No. IV. East of Craig Choinnichte it exists only at intervals on the north side of Strath Spean, and is there determined with difficulty. Indeed so great is this difficulty amid the broken debris and scattered blocks that cover the surface, that it is impossible categorically to assert of the different flats there exhibited that any one of them at special points is or is not the "Parallel," beyond a general coincidence of height at several places.

One point in particular was specially sought for by Mr. Melvin, of the Edinburgh Society, where, on the Ordnance map, a sudden change of twenty feet in the level of the "Parallel" is shown! This spot we found after considerable search, and the conclusion was forced on me that, under the peculiar difficulty or impossibility of accurate determination, it was undesirable, at this portion of the valley, categorically to put down the "Parallel" at all. This caution is all the more necessary where the "Parallel" seems to show such an extraordinary change of level at the top and bottom of a rocky hammock. Surely, no argument can, in the circumstances, be rightly based on any such variations of height as are here exhibited on the Ordnance map.

5. The Mouth of Loch Treig.—We now drove across the Spean and the Laire to Inverlaire House, where, scattered at ease on a grassy slope, under umbrageous fir-trees, we had our Spartan lunch, supplemented by abundance of excellent milk from the farm and the coolest and clearest of water from a neighbouring spring—the water being qualified by some members, and all the viands seasoned with appetite. Thence we proceeded to the entrance of Loch Treig, where we traversed the mountain side for some hours.

The narrow mouth of this loch is extraordinarily glaciated; in fact, it exhibits the strongest evidences of intense glaciation in this country with which I am acquainted: and I have seen the best of those in the Highlands. On its west side, above the stepping-

stones at the extremity of the lake, the rocks in the narrow pass show not only beautiful polishings and striæ, made by the ice on its *under* surface, but also others formed by *lateral* pressure; and, at one place, the results of *upward squeezing* on overhanging rock, which has been ground into the finest curves. Time prevented our visiting this last interesting example, but many others sufficiently striking were seen. This glaciation reaches up on both sides of the pass to some 2,000 feet above the lake.

We climbed to a projecting rock which commanded a view of the whole of Loch Treig on both shores, with its steep banks and enclosing mountains. As seen from the other side of Glen Spean, and easily at the mouth of Loch Treig itself, "Parallel" No. IV. enters some distance *into the mouth of Glen Treig*. It is, therefore, a very important point to determine *how far up Loch Treig it goes*, whether it sweeps round the whole of Loch Treig or terminates at some place within its hollow. That it runs round Loch Treig to its head is maintained by Milne Home, who figures it as going round the whole lake in all his maps, and who now stands alone in asserting its existence round the whole lake, though it had been previously suggested by Dick Lauder. Our party gave the most careful examination to the banks of the loch, and inspected it on both sides of its mouth. Including Mr. Livingston, of Fort-William, who knows the ground as well as, if not better than, any man, we *came to the unanimous conclusion that no evidence whatever is shown for the existence of this "Parallel" round Loch Treig; but that it ceases suddenly and symmetrically on both sides of its mouth at a point inside of the stepping-stones*, as laid down in the Ordnance Survey.

For years, I have myself examined the place from every point of view, (having stayed repeatedly at Fersit, near the spot, and having travelled the lake from end to end,) and again and again more particularly after the publication of Milne Home's opinion; and I have never seen the least grounds for the assertion that the "Parallel" runs rounds Loch Treig. On the other hand, I am prepared categorically to give it a direct denial.

This negative decision on this point has the most important bearing on the various theories adduced to explain the "Parallels." It pronounces strongly against both the marine and the detrital dam theories, according to which the lowest "Parallel" ought to enclose Loch Treig. But it is a strong and striking fact in support

of the glacial theory. In my opinion, it forms one of the best arguments in its favour, though it has not yet been adduced by writers on the subject. I hold that No. IV. was dammed back at the point in the mouth of Glen Treig, where it ceases, by the Treig glacier when it had shrunk back entirely out of Glen Spean; that this glacier occupied the deep hollow of Loch Treig during the whole period of the existence of the lowest Lochaber lake; and that the existing blockage to the lake at the stepping-stones is, in all probability, part of the terminal moraine, which marked its then existing boundary. This blockage runs like a steep, narrow bar between the loch itself and a lower pool, and descends rapidly into the deep water on both sides, especially on the upper, where Loch Treig suddenly deepens; and over it the waters of the loch gently ripple in so shallow a stream that stepping-stones have been placed in the current.

6. The Moraines above Fersit.—We crossed the Treig, which was lower than I had ever seen it, at these stepping-stones; while a young Hercules of our party waded the river with an elderly member borne Atlas-like upon his broad shoulders, amidst the plaudits of the party and the echoes of the hills.

The glaciation on this side, on the northern slopes of Garbh Bheinne (the Rough Ben), which bounds Loch Treig on the east, is unusually strong and fine, and is found up to some 2,000 feet. It is, of course, much better the lower down it occurs, on account of the greater pressure of superincumbent ice. It is exhibited in splendidly rounded *roches moutonnées*, with the lee or rough side looking *away from* the loch, in smoothings and polishings, in long, well-rubbed groovings and flutings, and in scratches and lines down to the most delicate striæ; for the rocks here preserve the whole with uncommon crispness and permanence. The contrast was remarkable between the general aspect and outline of the rocks as viewed from above, next the loch, where they were beautifully curved and rounded like the sleek flanks of a racehorse, and as looked at from below, where they were ragged and precipitous—a good illustration of the two sides of the famous shield, as well as a striking proof of the passage of the icy stream outwards into Glen Spean. It was the unanimous opinion of the party, that, as a whole, they had seen nothing equal to the glacial phenomena so abundantly and powerfully shown at this pass of the Treig.

It was also specially noted that the striæ, scratchings, and

flutings gradually curved or rayed outwards from the narrow pass, as the ice itself must necessarily have done, when, after being released from the confined bounds within, it spread over the broad strath in front,—a fact specially noted by Agassiz and Jamieson.

Rising along the slopes of the hill above Fersit, we soon came to the ridgy mounds of the moraines we had observed from the far side of the strath. Four of these are well marked above Fersit, though they increase in number to the east. They are put down by Milne Home at 1,120, 1,165, 1,175, and 1,480 feet above the sea—that is, from 500 to 900 feet above the Spean. The highest, however, is considerably above the 1,500 feet contour as laid down on the Ordnance Survey and as observed by myself—that is, over 1,000 feet above the valley at the junction of the Spean and the Treig. We followed the best marked ridge, which runs along the hill face and is separated from it on both sides, being laid down there like a huge embankment roughly prepared for a railway. In some places, it is 30 or 40 feet high, even on the upper side, and 40 to 100 feet wide. It consists of rough sandy, gravelly and earthy detritus, with embedded stones and boulders, many of the blocks being large. These ridges gradually near each other, and for a short distance coalesce, under the steep front of Craig Dhu; and then separate again to still greater distances, when the coercion of the hill allowed the ice to expand on the flat plain of Sliaber Lorgach beneath.

From this Craig Dhu one of the finest views of the great Horse Shoe Moraine curves can be obtained, seated as you there are, at the exact diagonal distance from the other point of sight on Craig Choinnichte, four miles off, in a bee, or rather in an eagle, line. Here you look down with ease on the gigantic circles which unite under your feet and sweep so splendidly across the rough moor below. Here also the older, outer, less defined, and less continuous curves may be observed resting on Meallan Odhar and Meall Liath to the east, and Meall Clachach across the Spean; while the whole plain is covered, in wild confusion, with a thousand boulders. The varied character of the curving lines may also be well observed from this point, and their occasional uniting and separating, as shown on the Ordnance map—with the kaim-like character of some of them, as consisting of finer debris, and the trainées of grey blocks that form others. The whole phenomena present a striking and uncommon sight, which enables the beholder vividly to realize

the glacial past, during which the wide strath was filled with the gleaming *mer-de-glace* of the Treig, as it lay enclosed by its heaped moraines.

The scenery, moreover, is a worthy framework for such a picture, stretching onwards to the serrated peaks of Arasaig and Moidart, in the long-drawn distance down the Spean. Our party were inclined to agree with Jamieson, when he says that "these moraines, together with the ice-worn gorge, afford about as good evidence of the former existence of the Glen Treig glacier as a fossil skeleton does of the former existence of the living animal." *

7. The Blocks of Sliabh Lorgach.—Descending the hill, we reached the drove-road to Rannoch, and followed it back to Fersit and our carriages. On the way, we were moving through part of the multitudinous blocks we had seen from above, some of them gigantic, grouped and piled in the wildest style. They consist mostly of grey syenitic granite, mixed with masses of porphyry, chiefly red, with schist and gneiss, the proportion of the last to the granite being very small.

This syenite occurs here *in situ* over the whole floor of the valley to the east of the Treig and across the Spean above Roughburn. It forms a special point in Jamieson's paper; but it is there imperfectly mapped, as he was unable to determine its S.E. boundary. This I have since done, and shall describe in my forthcoming paper before the Royal Society. It extends some miles to the S.E., and includes Craig Dhu and Cnoc Dearg up to 3,000 feet. It is assuredly the source of a large part of the granite blocks so abundant in Glen Spean. It seems certain that, on the other hand, many of these came also from the head of Loch Treig and neighbouring valleys; and that the more elevated ones, such as those on western Craig Dhu, came from sources as yet unknown, probably from the westwards. Jamieson seeks too much to draw them from the narrow bounds of Sliabh Lorgach, the plain below Craig Dhu of Fersit.

Along the drove road, the bare rock *in situ* is exhibited, finely scratched and polished, especially in places recently exposed which I had not seen before; for the granite surface, wasting rapidly away, speedily obliterates them.

Where the road crosses the Alt Chaorach, or the Sheep Burn, our weary travellers refreshed themselves by one and all "paidlin' in

* "Parallel Roads," *Q. J. G. S.* 1863. P. 249.

the burn." Thus employed, they presented a picturesque and happy group, which will ever afterwards be recalled when they hear or sing Scotland's immortal song of friendship.

Soon we were bowling along Strath Spean in the evening light, while the western sky glowed before us over the distant hills. After due refreshment, fairly earned by the long but charming day's labours, we were soon sunk once more in grateful and renovating oblivion.

IV. UNACHAN AND CORRY 'N EOIN.—

Thursday, July 30th.

1. The Mountain Chain of Nevis.—The following day, bright and pleasant as before, was devoted to an examination of the inferior endings of the lowest "Parallel" down the Spean, and of the great Corry 'n Eoin, the Corry of the Bird, that is the Eagle. Out of this corry came one of the largest lateral glaciers which helped to block the ancient lake at its lower termination, according to the glacial hypothesis, and which figures so great in Jamieson's famous paper.

We drove to Spean Bridge, and then across the broad-backed ridge of Unachan, to the farm of Lianachan, where we left our carriages and took to the hill. On the way, we obtained splendid views of the great mountain screen of the Nevis range, right opposite, and of the glens that contributed their ice to that of the Spean; especially the Larig Leacan, along which passes the great drove road to Rannoch and the south, by the head of Loch Treig. This glen shows intense glaciation to a great height, and through it (for its summit level is only 1,650 feet) passed part of the vast accumulation of ice that gathered at the back of the Nevis mountains and forced outlets to itself in this direction by the Treig, the Laire, and the Larig.

2. The Ridge of Unachan, as it is called in several papers, whose real name is the Mointeach Dhubhe or the Black Peat Bog, lies between the old course of the Spean along which the high-road to Fort-William runs, and a still older course of the same river, through the hollow valley close to the mountains, which is now drained by tributaries of the Loin and the Lundy. Unachan seems to be a great rounded *roche moutonnée*, with a central rocky core, covered with glacial debris, which is hidden by deep

peat and moss. Across it run diagonally the long kaim-like lines described in Mr. Livingston's paper, as already noted. It is supposed by Jamieson to be the remains of the moraine matter laid down by the glaciers that here dammed back No. IV. ; and by Milne Home to be the remains of his huge detrital dam, which did the same work. It is so swaddled in peat, however, that its real structure cannot well be ascertained. At the summit of the ridge, a wide-spreading view on all sides is obtained of the surrounding country up Glen Spean and Glen Roy, the parts already examined by us, and over to Loch Lochy and Loch Arkaig in Glenmore. The termination of No. IV. on the north side of the Spean, above Blarour, was well observed; its line, after coming out of Glen Collarig, running continuously along the front of Meall nan Luath and ending suddenly, without further sign, to the east of the Blarour burn, at a point marked by a small tree.

3. The Termination of the Lowest Road at Corry Choilzie.—Farther over, at the other side of the Unachan ridge, we looked down on the hollow valley of Lianachan, an old course of the Spean, already mentioned, and into the mouths of Corry Choilzie and Corry 'n Eoin ; and we had the whole Nevis range open before us.

The determination of the point where No. IV. ends on this side drew our attention, as this has been a matter of dispute. The "Parallel" was easily observed running along the front of Ben Bahn, which rises between Larig Leacan and Corry Choilzie. There it seemed as suddenly to terminate as its companion "Parallel" on the north side above the farm of Corry Choilze to the east of the entrance of the Corry itself ; and there it is made to terminate in the Ordnance and most other maps. But Milne Home, the great dissenter on this subject, again following Dick Lauder, maintains that evidences of it exist to the west of this point, in the mouth of Corry 'n Eoin itself; though he allows, with Lauder, "that the traces of the shelf here are faint," * and admits that it does not appear on the hill between Corry Choilzie and Corry 'n Eoin. His desire to find the "Parallel" in Corry 'n Eoin is most natural, for Jamieson unguardedly admits that he "should have considered it a good objection to Agassiz's theory had any of the "parallel roads existed in this gully." † I consider this admission

* See his second paper of 1877, p. 100.

† See his paper of 1863, p. 246.

to be unnecessary and unfortunate; but this is not the place to discuss the subject. Our party, with one exception, were of opinion that no evidence of the existence of the "Parallel" can be seen beyond the point laid down by the Ordnance Survey. One member thought it possible that certain patches at the hollow where the river issues from the glen might be at the same level as No. IV., but that it would be difficult to assert that they were part of the "Parallel." I have myself, in some lights, thought I discerned slight traces of a level at or about the same height as No. IV. in the mouth of the corry at the Cour; but I am strongly of opinion that no decided statement can be made in favour of the existence of No. IV. beyond the usual ending assigned to it, above the farm of Corry Choilzie. West of the Cour, not even Milne Home maintains its presence. But the discussion of this point and its relations to the glaciation and the "Parallels" must be reserved.

4. Corry 'n Eoin.—This is a profound rocky glen lying between the great mountain of the Aonach, most of which is about 4,000 feet, one of the highest in the range, and Ben an Socaich, which separates it from Corry Choilzie. Its sides are precipitous and bare all round, and in grandeur it is not surpassed by Corry Lees or Glen Nevis, which enclose the great Ben. It is much shorter than these glens, being in truth a corry, as it is named, more than a glen. Its head is as high and steep as its sides and possesses no col, its lowest notch not descending below 2,400 feet. It is drained by a stream called the Cour, which, fed by numerous tributaries, soon becomes a considerable river. It is eminently worthy of a visit, for its scenery and for its splendid glaciation, which has been intense and reaches up its sides above 2,000 feet.

Accompanied by a young and stalwart Highlander, and shortly joined by his father, the head keeper, we ascended right into the glen by the high ground to the west of the Cour. We passed some bare rocks covered with grooves and scratches. These were unusually long and deep, and ran parallel to the Corry and at right angles to the Spean. Time prevented our seeing some still finer, which are the best I have seen in these mountains, and are not surpassed in the country.

In the middle of the Corry rises an eminence called An Guirean, which is a peaked boss of rock, steep on all sides, and mostly bare. It is, in fact, a huge *roche moutonnée* which has been swathed in the ice sheet that filled the glen, set in its very centre as if to prove

its depth and power. It is rubbed, scratched, and smoothed all over, especially on its upper face and head, though the rocks that compose it have not preserved the finer scratches and grooves like others below. The contrast between its stoss or upper side and its lee or lower side is remarkable; the upper being rubbed and rounded, and the lower showing an untouched rugged front. We climbed to its summit, which commanded a wonderful view on all sides. Above we gazed into a profound hollow corry pot, formed by the scarred precipices of the Aonach and its companion peaks. This was first the steep cradle of the old glacier; and afterwards the bed of a lake now drained. This formed a wildly grand and impressive solitude. On the other side, we had glimpses of the outer world across Glen Spean, and away beyond the Great Glen to the mountains at the head of Loch Arkaig.

5. The Lake Dams Required.—From the heights at the entrance of Corry 'n Eoin, a vivid conception is gained regarding the barrier which held back the waters of the great double-breeched lake that formed the lowest "Parallel," with its long limbs stretching upwards into the far ends of Glen Roy and Loch Laggan.

The demand of a detritus dam between Corry Choilzie and Blarour is seen in all its magnitude. We are asked to believe that such a dam filled the strath below, from side to side, and held back such a lake. This dam would require to be four miles in length; at least 500 feet in height above the nearer valley of the Cour, and 600 feet at the Spean; and miles in breadth to withstand the hydrostatic pressure of so great a mass of water. It is also asked that this immense mass of debris shall be placed here where there is no apparent or adducible reason for its existence. Further, we must concede that it has vanished or somehow been removed, and left not a trace of the mighty embankment, except the ridge of Unachan and the low gravel deposits of Glen Spean. It is a large demand on faith and a heavy burden on reason; at least, so thought and said the party that then looked across Glen Spean.

On the other hand, the magnitude of the glacier dam that is required for the work assigned it, is also strongly exhibited from such a position, and the need shown of possessing correct conceptions regarding it, if this theory is to be finally accepted. These can only be obtained by a careful and detailed study of the glaciation of the whole district in question; and nothing has impressed

me more than, on the one side, the imperfect presentation of the glacial theory by its advocates, and not less by Jamieson, its best and most logical expounder; and, on the other, the manner in which it has been misunderstood, especially by Milne Home, its chief opponent, and even by Professor Prestwich—all from deficient knowledge of this general glaciation.

On the one hand, I agree, with Professor Prestwich and Milne Home, that alone "the Glen Treig glacier would be incompetent to the task assigned to it" by Jamieson; and that Jamieson's summary of the subject is inadequate when he says—"Grant two ice streams, one in the Great Caledonian Valley (taken in conjunction, as he explains, with the Corry 'n Eoin glacier) and the other at Loch Treig, and the problem of the 'parallel roads' can be solved." On the other hand, Prestwich's criticism is based on an imperfect presentation of the glacial theory; and Milne Holme's is all through an unconscious but unintentional travestie. Thus writes Milne Home—"It seems really almost impossible to believe that a glacier formed in any of these Lochaber corries should have produced tongues of ice more than twice as long as the glaciers themselves, and that these tongues should, at their tips, have formed permanent ice barriers." "Mr. Jamieson," he continues, "brings together, to form his ice barrier for shelf IV., no less than three tongues—one from Corry 'n Eoin, one from Arkaig, and one from the Great Glen. The meeting of these three ice-tongues, coming from opposite directions, would be a very remarkable conjunction indeed if it had the effect of producing a solid barrier of ice." No doubt it would, if they were asked to do it; or if they were all the ice available for the work. And he triumphantly asks, "How is it possible to suppose that merely the tongue of a glacier from the Treig valley—a tongue wending its way across valleys and round hills for five or six miles could dam a lake such as that which filled Glen Roy?"* Milne Home's tongue has run away with him in such a description of the theory he opposes. I am bound, however, to admit that my good friend and leader, Mr. Jamieson, is partly to blame for allowing him no small grounds for his caricature, by giving certain glaciers too much to do, and by not using others equally willing and able to assist in the work.

*See Milne Home's Paper for 1876, p. 629, and the Tenth Report of the Boulder Committee, p. 161.

6. The Sources of the Ice Dam.—Shortly, the case for the ice may be thus stated. Glaciers descended into Glen Spean from the Nevis range, the highest in the country, not only from Glen Treig and Corry 'n Eoin, but down the Laire, through the Larig Pass, and out of Corry Choilzie, Glen Rois, the Glen of the Lundy, Corry Lees, and Glen Nevis—each of these contributing its quota to the general accumulation in Strath Spean. The Spean is, besides, topographically so situated at right angles to all these glens as to receive into its own basin not merely the united contributions of the glens that open into it on that side of the mountain group, *but also the greater portion of the vast glacial ice that concentrated at the other side of the group*, in the Nevis-Rath glens. From their configuration the Nevis-Rath glens were compelled to disgorge the most of their ice *through the mouths of the Treig, the Larig, and the Nevis.* The ice that thus filled Strath Spean was, for these reasons, so great that it even forced a passage for itself at one period out at the head of the Roy, and at the far end of Loch Laggan.

But this is not all. The accumulated ice of the Spean was further augmented, and retarded in its place, by that existing in the Great Glen, gathered there from its large lateral valleys, especially from Glen Arkaig,—ice which, at one time, also pressed its way up Glen Gluoy and out at its head into the Roy. This ice of the Great Glen was yet further added to by powerful glaciers coming partly down Loch Eil and through Glen Loy.

Moreover, the seaward outlet for this immense accumulation of glacial ice was remarkably constricted at the head of Loch Linnhe and down its narrow throat, the only outlet to the outer ocean. Its outward passage was further obstructed by the overflow of ice from Glen Nevis at the vitrified fort of Dunjardil, and by the still stronger mass pressing it at right angles at Ballahulish.

There thus arose an immense, nay extraordinary, congestion of ice in the lower ends of the Great Glen and Glen Spean, such as existed nowhere else in the country, and such as could only exist under such concentrating and constricting geographical conditions. Ice! Instead of too little of it, as loudly complained by Milne Home and others, we have enough and to spare for the work we ask it to do. Nay, its amount is embarrassing and compels the glacialist carefully to consider when and how it acted as the ice dam he claims it to have been; to examine into the portion of the

glacial period when it did this work, the manner of its retreat, the pauses it made, and its whole relations to the "Parallels."

But this is not the place to enter into these questions. I merely wish here to indicate that there is more ice available for the special function attributed to it than either its friends or its enemies seem to have dreamt of. And these sources of glacial ice are proved, beyond all question, to have existed and coalesced, by a detailed examination of the glaciation of the region. After a delightful lunch at the farm of Lianachan, in full view of these glens and mountains, we drove back to our hotel. This was our last evening together as a whole party, more than half of the members leaving that night for Fort-William or next morning for Kingussie. Before separating, we reviewed the work of those happy days with mutual gratulations and pleasant speech, resolving, if possible, that this should only be the first of similar re-unions in the coming years. Six of us, all belonging to the Glasgow Society, remained behind at Roy Bridge, in order to complete the survey of the wonderful phenomena we had come so far to see.

V. ROUND BOHUNTINE HILL—THE GAP AND GLEN GOLLARIG.

Friday, July 31st.

We drove up Glen Roy to the grand point of view above Achavaddy, climbed through the "Gap," between Bohuntine Hill and Leana More, along "Parallel" No. II., the highest in Glen Roy, and onwards down Glen Collarig, and across the Alt Ionndrain, which drains it, back to the hotel. The weather still smiled on us. The phenomena exhibited were interesting and striking, and the points of discussion numerous and important; so that, altogether, it formed, perhaps, the most instructive day we spent in connection with the problem. It enabled us somewhat to gather the threads we had been spinning during the week into a firmer and more satisfactory clue. It is only a pity the whole party did not help to wind it.

1. The "Parallels" in Glen Roy.—The view of the "Parallels" was the best we had obtained, the morning light and deepened shadows bringing them out in wonderful relief against the hillsides. By their closer inspection as thus seen, and by an examination of the Roads themselves on the spot, we were enabled to come to more definite notions on several points than at our first journey up Glen Roy.

(1.) We were impressed with *the extreme difficulty of accurately taking the true levels of the Roads at the different parts of their course.* As has already been adverted to, the Roads at many places cannot well be made out when you stand upon them, though their line is well enough seen from a distance. Thus different opinions would be held by different observers as to their exact boundaries both above and below. These difficulties of determination would, of course, give rise to differences of opinion regarding the exact point at which the level of the Roads should be taken at successive places. This accounts, to a great extent, for the varying levels at which they are mapped, even where the Roads are more or less distinctly marked and bounded. Many of the variations in level, and in breadth and slope, as laid down on the Ordnance maps, are easily accounted for, through this dubiety of accurate determination.

(2.) *Other variations on these and other points were also obviously explainable by various local conditions*—such as the slope of the hill face, the character of the debris on which they are impressed, landslips which are pretty numerous and quite distinct, the cutting-through of the Roads by streams, and like facts.

(3.) *Obliterations*, as shown on the maps, *were also seen to be very explicable by various local conditions*—such as the presence of rocks at several places in the Roads, the extreme slope of the hill, landslips, weathering, the passage of torrents, which are often furious on such steep mountains, the absence of debris, the form of beach, etc.

(4.) These and other difficulties showed *the impossibility of mapping these ancient beaches with absolute uniformity and certainty* by even the best Government or other surveyors, however capable. Indeed, the work would require a committee of scientific specialists to accompany the surveyors, in order to determine height, breadth, and slope, and settle the exact point of levelling, all along the "Parallels," so as to have the work done with scientific accuracy. They also showed the caution that is needed in basing any reasoning or theorizing on such necessary variations in the present maps. It was certainly very obvious that too much should not be made of such variations—a tendency to which is shown by Prestwich, perhaps, more than any other writer on the subject. The Ordnance maps are undoubtedly sufficiently accurate for all practical purposes; though it must be confessed the observers might have shown

more scepticism as to their presence in many places than they seem to have done.

(5.) *The absence of notches or indentations on the hill face along the Roads* was noted. Only one such notch was observed—viz., on the sky line on the right or eastern side of the glen, on the face of Leana Mhor. The general correctness of Macculloch's early observation that *the Roads are laid down on the face of the mountains like a series of superposed parallelograms* was acknowledged.*

(6.) *The contrast of the contour of the Roads to that of moraines, especially those we had seen in these glens, was complete.* The Roads sloped everywhere at a low but varying angle down towards the centre of the valley, and their surface formed a straight line; while the moraines were ridgy, kaim-like, and irregular.

(7.) *The absence of water-worn stones was observed as a feature requiring special explanation* on any water theory, whether of sea or lake. If these terraces represented the shores against which water washed and worked during a more or less lengthened period, why were the stones that formed the beaches not rounded? This is a great difficulty which writers on the subject have not sufficiently considered. At first sight, it seems to be inexplicable on any aqueous theory. In my opinion, it appears to prove that the water that impinged against these beaches was *frozen over the greater part of the year*, and that the Roads were thus protected from the action of wind and wave.

(8.) *The lower termination of No. II., the highest Road in Glen Roy*, has been made a matter of controversy by Milne Home. According to the Ordnance Survey and all observers that have yet written on it, except himself, it ends at the S.W. angle of Meall Dhu, just where it turns round to form the northern side of Glen Glaster. In all his earlier papers, Milne Home agreed with this limit; but in his last, published in 1877, he holds that *it exists on both sides of Glen Glaster, and ends pretty well about the same place as No. III.*, which certainly runs round Glen Glaster. I have examined the glen from all points, especially since his publication of this opinion, and I have been unable to discover its existence beyond the old point generally agreed to; except, occasionally in certain lights, the slightest indications which possibly may or may not be parts of No. II. I was sorry that

* See Macculloch's diagram, often reproduced.

want of time prevented our party examining this important matter during this excursion, and thus helping in some measure to settle it.

If No. II. does end, as Milne Home asserts, above No. III., his detrital dam is relieved of one heavy burden, viz., the need of having it further up Glen Roy, and then suddenly retreating to where No. III. ends. But in this case also, the glacial theory is equally, if not more, relieved by not requiring the ice dam in Glen Glaster during the existence of the highest Glen Roy lake.

This point requires further observation for final settlement.

2. The "Parallels" in Glen Collarig.

(1.) We ascended Bohuntine Hill to No. IV., and walked along it to the opening of "the Gap." This "Parallel" does not enter "the Gap," for the summit level of the col which forms it is higher than No. IV.; but the two upper "Parallels," which are higher than the col, run into it on both sides. We climbed to the highest on the south side of the valley, running at a height of 1,155 feet, and went along its well-marked terrace. The Roads here are exceedingly distinct, with clearly defined inner and outer edges and great evenness of breadth. They end quite abruptly, as if suddenly cut off by some barrier which is now quite obliterated. There exists no accumulation of debris, either at their endings or across the glen between these points, to suggest any debris dam. Such a dam, it was felt, could not have been so entirely removed or "annihilated," to use Milne Home's own expression,* as it has been, if it once existed, especially in the immense quantity, both high and broad, that would be necessary to hold back a lake stretching ten miles onwards to the head of Glen Roy.

(2.) All round the Bohuntine Hill we noted fragments of the grey syenite, which is so abundant in Glen Spean, some pieces being above four feet in length. This syenite is also found up to the head of Glen Roy. Large blocks of it can be easily examined on the road side opposite Cranachan farm, where they have been split up for building purposes. Pieces of the reddish porphyry, found also in Glen Spean, are not uncommon all round Bohuntine Hill, but they are much less frequent than the syenite.

3. Milne Home's Blockage in Glen Collarig.—The relations of the Roads to each other are perhaps more remarkable in Glen Collarig than at any other place. No. IV., the lowest,

* Memoir of 1876, p. 116.

does not enter the pass at "the Gap," as already said, but it runs round the south end of Bohuntine Hill and enters Glen Collarig at its mouth. It is seen there on both sides of the valley, and seemingly terminates abruptly at the mouth of the side glen, called Corry Cheirsle. No. II., the highest in Glen Roy, enters "the Gap" above and exists on the hill face on both sides. On the north side, it ends at the corry in the angle whence descend the head waters of the Alt Ionndrian, which drains Glen Collarig. On the south side, it goes farther along on the face of Bohuntine Hill, to a point about two thirds of the distance between its ending on the north side and the termination of No. IV. No. III. also runs into "the Gap" on both sides, and continues farther south than No. II., till about half the above distance, where it disappears symmetrically on both sides.

These varied terminations and relations of the Roads to each other in this glen are made much of by Milne Home in his two papers on the subject. They are, in fact, adduced by him as a crucial test in favour of his theory, and against the glacial theory. He has referred to it frequently since then by way of challenge, as at the meeting of the British Association in Glasgow, and at the meeting of the Edinburgh Geological Society on the 7th of May last, when this excursion was resolved on. For his argument the reader is referred to his papers, and especially to the first, published in 1876, and to the illustrative diagrams. He places a detritus dam right across the valley between the endings of the "Parallels"; for the double purpose of holding back the waters of No. II. and No. III. above, and of No. IV. below.

The subject can only be treated here very shortly, but sufficiently, perhaps, to indicate the line of reply.

(1.) Milne Home holds that a blockage is necessary to dam back No. IV., the lowest Road, at its upper end near Corry Cheirsle. I have frequently examined the valley, especially since the publication of Milne Home's memoirs, and have found that this "Parallel" does not end symmetrically on both sides, but extends farther north on the east side upon Bohuntine Hill; that beyond the point where it seems to end, the bottom of the valley gradually rises to the height of the road and is filled with rough debris; and that this "Parallel" loses itself in this debris till the valley reaches the level of itself at the upper part of the glen, where the Alt-na-Ceardaich joins the Ionndrain. Beyond the apparent

termination of No. IV., the lake would thus be very shallow, and become, in fact, a rough marsh, ill adapted to form and retain a terrace or "Parallel" at its outer shores.

Similar ill-defined or altogether obliterated endings of the "Parallels" occur at most if not all the upper portions of these glens—at the head of Glen Roy, where No. II. only exists in detached patches; at the col between Glen Gluoy and Glen Roy, where the Gluoy Road No. I., on the one side of the col, and No. II. in Glen Roy, on the other side, gradually die out into indistinctness or nothingness in the debris at the bottom of the valleys; at the head of Glen Glaster, where both No. III. and No. IV. are also indistinct, equally in the valley of the Glaster Burn and at the col between Craig Dhu and Craig Uilleim; and again at the upper end of No. IV., round Loch Laggan, and also before reaching Loch Laggan, at and beyond Roughburn, where it is most fragmentary, and for miles entirely unseen.

This indistinctness or partial or total obliteration at the upper ends of these "Parallels," where the water became shallow at the heads of the glens, seems universal. It is a phenomenon to be naturally expected in the shallows there existing in the waters of the lake.

No blockage is therefore necessary, I contend, for the upper end of No. IV. in Glen Collarig. Such also was the opinion of the party that accompanied me.

(2.) Milne Home's blockage is placed there to hold back No. II., the highest "Parallel," which ought, therefore, to reach down to it *on both sides.* On the north side, unfortunately for him, it terminates at the angle where the Ionndrain descends from the hill, and *not a trace of it is visible between that point and the dam thus laid down.* This is acknowledged by Milne Home himself, who puts it down on his own map as "not traceable." No. II. on Bohuntine Hill also does not come up to his dam, for it stops some distance short of No. III. No. III. alone ends at the blockage for which he contends. So that, on the upper side of his "dam," there are as grave difficulties against it as on the lower, in regard to the terminations of the "Parallels."

(3.) As already said, there is no trace in this part of the glen of such a large accumulation of detritus as would be required to form the formidable dam requisite for such a lake. The narrow dam Milne Home figures would, from an engineer's point of view,

be quite insufficient for the duty. The hill sides have the same even slope there that they exhibit all along the rest of their course on both sides, and the regularity of slope and face is a marked feature of these Lochaber glens, especially in Glen Roy and its lateral chambers.

Altogether, unless pressed by the irresistible exigencies of a theory, most observers would be safe in saying that no person would assert that such a dam, 1,100 feet at least above the bottom of the valley, ever existed at this part of Glen Collarig.

CONCLUSION.

After crossing the Ionndrain below Corry Cheirsle, we walked along No. IV. into the pastoral hollow of the Bo-loin burn, where the signs of old habitation are seen. Crossing the stream, we ascended the bare and peaty hill called Maol Ruadh, which is the site of a fierce clan battle. There a wonderful view of the whole district we had traversed during the week was obtained, from Fort-William to Loch Laggan and up Glen Roy, and appropriately closed our examination of the world-famous Parallel Roads of Lochaber.

No. VI.—A Glimpse of Skye: with Remarks on Volcanic Action. By James White.

[Read 16th October, 1884.]

Our "stern Scottish Highlands" afford an unrivalled field for the study of physical geology, that very poverty and barrenness which characterize the larger portion of them being due to causes which at the same time constitute their scientific wealth. The extreme irregularity of their surfaces, their lofty mountains, numerous lochs and ravines, and deeply indented seaboard, are all features which add greatly to their value as a field of geological research. Sections are there to be found which we could never otherwise hope to see. The deep glens and abrupt sea-cliffs show the relations of rock to rock, of strata to strata, which cannot be seen elsewhere. Only where it pays by the minerals it yields, can we afford to open up the crust of the earth to see how it is made. We are dependent on Nature to do the rest, and it does it right well in the Highlands.

By what other means could we ever hope to have dissected for

us a burning mountain? A voyage to the moon is not more impracticable than to descend a volcano to examine and criticise its lurid processes. But here we catch it when it is old and out of vigour, and get beneath, if not behind, its most hidden operations.

A sail across these western seas from Oban to Skye is full of interest to the geologist, and particularly to the student of igneous rocks. Here we pass in succession no fewer than four volcanic centres which, in times so late as the Miocene, have poured out lavas of immense extent, whose scattered and fragmentary condition shows that they are merely a tithe of what they have been. The *Puys*, or old volcanic cones which stud the granitic plateau of Auvergne, in central France, and which are so well preserved that, but for the circumstance that they are cold and quiet, you might take them to be in a state of activity, are referred to the same geological period. The respective states of preservation of the two series are a striking testimony to the destructive effects in these more northern latitudes of the great ice age and the eroding power of the sea.*

Leaving out of view for the present those old Laurentian rocks which mark the outermost border of our country, the principal surface rocks of the region are those Tertiary volcanic rocks which Professor Judd has of late years so ably investigated and described.†

Vulcanicity has played so important a part in the formation and modification of the crust of the globe, that it may be of some interest if we endeavour to place before our minds as concisely and accurately as possible what is really known on the subject.

At present there can be enumerated all over the world, on land and in the sea, about 400 of these volcanic fires in a state of greater or less activity—literally turning the globe inside out. It has always been so; for while active volcanoes can be counted by the hundred, extinct volcanic centres may be reckoned by the thousand; and, however paradoxical it may appear, this is really one of the conditions of a planet capable of supporting life as we know it. A planet that loses the power of internal

* See Prof. Hull, *Jour. Roy. Geol. Soc. of Ireland*, vol. iv., page 30.

† See his admirable papers in the *Quarterly Journal of the Geological Society*, vols. xxx., xxxiv.

change, as a necessary result loses the power of sustaining living things on its surface. A little consideration will make this plain. Epigene agencies disintegrate the hard rocks and prepare soil whereon plants may grow; these plants become the food of animals; but the soil becomes exhausted and requires to be renewed. Denudation does this, carrying away the effete material to the sea, whilst the frost breaks up the hills to supply more. But it is obvious this cannot go on for ever; without compensating movements from beneath, the system of things would in time become exhausted, and all be reduced to the level of a dead uniformity. But elevatory movements and the volcano step in to play their part and to restore to terrestrial life that material and those irregularities without which it could not exist. And not only are those changes necessary for the continuance of life, they are equally necessary for its development. It is by the ever-changing environment of organic beings that new forms are evolved and the fittest preserved. In vulcanicity, therefore, we have a link in the chain of causes of which we see neither the beginning nor the end, but can see that progress is secured by an ever-increasing adaptation to complex conditions.

When we begin to make some inquiry as to what are the *causes* of volcanic action, we are at once led into an immense arena of speculation and discussion. Let us keep as closely as possible by ascertained facts.

From the testimony of many independent witnesses who have had the good fortune and the temerity to observe it in active operation, it would seem that the behaviour of lava in a volcanic vent, and the method of its ejection, is more akin to that of boiling or ebullition than to anything else that we know. The lava is seen to surge up and down, backwards and forwards, and with a circular motion accompanied by frequent discharges of steam, in a manner precisely similar to any viscous body when subjected to the action of heat. This is a process with which we are familiar; and there seems good reason to conclude that the overflow of lava is due to the same cause, viz., to the expansion of the contained gases, to steam. The question then arises, What is the source of the heat which causes the disturbance? There is (1) the latent heat of the globe, which can be detected and measured the farther we descend into the interior; (2) heat arising from chemical action; or, (3) heat developed

by mechanical action, viz., friction or crushing. According as one or other of these sources has been regarded as the efficient source, have the various and sometimes opposing theories of volcanic action arisen.

All recent explorers in this department of knowledge have abandoned the idea of chemical action. Whatever may have been the case in the earlier stages of its history, the earth is now too old and settled to admit of anything of that sort. The chemical affinities and repulsions of matter, on anything like the scale required, are believed to be long since satisfied, and nothing is left of this nature sufficient to support volcanic action. The prevailing idea is that it is due in some form or other to the latent or residual heat of the globe, and that the interior of the earth is probably a kind of cavernous, honey-combed structure, containing numerous lakes or reservoirs of molten matter, the invasion of which from time to time by water occasions volcanic action. This structure, it has been argued, would give to the astronomer the rigidity required to account for its behaviour as a planet,* and to the geologist the amount of free material required for its eruptions.

But an eminent writer on this subject—the late Mr. Robert Mallet, F.R.S.—was not satisfied with this explanation, and propounded another, and, as he believed, the true theory of volcanic phenomena, bringing into view the third cause above referred to, viz., mechanical action. He described as a "lame and gratuitous hypothesis" the idea of lakes or isolated masses of fluid-rock existing at different points and different depths, from which volcanic vents are supplied, and returned to the hypothesis of a central hot and liquid nucleus, surrounded by a colder and solid shell. Let me give his definition of his theory in his own words :—

"The heat from which terrestrial volcanic energy is at present derived is produced locally within the solid shell of our globe by transformation of the mechanical work of compression or of crushing of portions of that shell, which compression and crushings are themselves produced by the more rapid contraction, by cooling, of the hotter material of the nucleus beneath that shell, and the consequent more or less free descent of the shell by gravitation, the

* See Sir W. Thomson on "The Internal Condition of the Earth," *Transactions*, vol. vi., p. 38.

vertical work of which is resolved into tangential pressures and motion within the thickness of the shell." *

The main portions of this theory rest on undoubted facts, which give to it an air of strong probability. Of tangential strains in the crust of the earth, and those of tremendous severity, let the gnarled, crumpled, and contorted schists of these same Highlands bear witness. But unless these rocks had been forced down into a space much less than they originally occupied, they could have had no such compression ; and if that which is beneath them were rigid and would not yield, how could they have sunk? And it is obvious that such friction and such crushing must have evolved very great heat. Faulting is always accompanied by abrasion of the rocks, giving rise to heat. Mr. Mallet points out the linear character of volcanic foci, and that they are on lines of weakness in the crust.

But in the midst of our musings our sail comes to an end, and we are landed at Broadford on one of those patches of highly fossiliferous Secondary strata which Hugh Miller described so well, and on the confines of one of those denuded volcanic centres which Professor Judd has brought so vividly before us.

The whole of the northern and greater part of Skye consists of immense sheets of volcanic rocks overlying the Secondary series ; and it would be difficult to find a locality where the beautifully-terraced form characteristic of that formation can be more distinctly seen. The hills on every side rise with almost artificial regularity, step by step, to the summit.

The southern portion of the island presents no features which call for special notice, but in the centre there rise two groups of hills which are so strikingly different from each other, and from all others even in this tumultuous land of hills, that they arrest the attention of every passer-by. Those in the foreground from our point of view are the Red Hills, remarkable for their rounded pyramidal forms and red debris-strewn sides, on which vegetation is almost baffled to find a footing. The black and serrated peaks in the background are the " wild, jagged, and fantastic outlines " of the Cuchullins which we saw so well as we left Eigg and crossed over to Arisaig. The Red Hills are masses of granite, the Cuchullins masses of gabbro. The gabbro is younger than

* See an elaborate paper published by Mr. Mallet in the *Philosophical Transactions* for 1873, worthy of a most careful perusal.

the granite, for numerous veins of it intersect the latter; they are both deep-seated, highly-crystalline intrusive rocks—"plutonic rocks" of the text-books. The strata through which they have been protruded are very much disturbed and metamorphosed, the arenaceous rocks being converted into granitoids and the limestone into marble.

Volcanic rocks are divided roughly into two classes, the one earthy or fragmental, the other glassy or crystalline; the former represented by volcanic ash in its numerous forms, from the finest comminuted dust to the rough and stony agglomerate, the latter by our familiar dolerites, basalts, and pitchstones. A distinction sought to be maintained among the crystalline rocks was between the plutonic and volcanic; this distinction Professor Judd's researches among these "grand old igneous springs," cooled reservoirs of ancient volcanoes, shows to be a purely artificial one; the one being simply the root, the other the stem and branches.* Other observers in other localities describe rocks similar to these gabbro rocks as "Granitones," and trace a connection as unbroken between the basic and the acid series. Mr. Clifton Ward found this to be the case with some of the igneous rocks of the lake district, to which he gave the compound name of "Felsi-dolerites"; so that we can only say with regard to all of them that they consist of matter which has been thoroughly fused, into which water, everywhere present in the earth's crust, has found its way, with the result that by the formation of steam, part of it has been blown to the surface, part injected with great force into the surrounding rocks, the remainder being cooled and crystallized at greater or less depths. All this has doubtless gone on from the earliest stages of our planet's history. The shell cools and solidifies from without; it is constantly being displaced and replaced by matter from within. Thus we come to have, even in these deep-seated eruptive gabbros—these roots of volcanoes—only the extreme of metamorphism after all; the crystalline being the most highly differentiated form which inorganic matter can assume. It is common to speak of the sedimentary rocks as "derivative"; it is just as correct to apply that term to the crystalline.

It is quite a sight to see the glaciation of these wild Cuchullin hills. We Lowlanders with our soil-clad plains can only see these

* See paper in vol. xxx. of the *Quarterly Journal of the Geological Society*, already referred to—a veritable romance of physical geology.

features on a small scale in stubborn projecting bosses here and there, or in the "tirrings" of quarries; but these hard hypersthene rocks, so utterly innocent of soil or verdure, show it with great distinctness, and on the grandest scale. Forbes, Geikie, Judd, and others have called attention to this remarkable spot.

Specimens shown—

1. Several weathered and fresh specimens of the gabbro of the Cuchullins, and some of the dolerites and basalts into which it passes. These are mostly dykes; but some chips also shown of the overflow lava—one from Portree and two from the Quiraing.

2. Granite from a boss on the shore at Loch Slapin.

3. Weathered specimens with the felstone into which it graduates, from the flanks and top of Ben-na-Cailleach, one of the Red Hills, 2,400 feet.

4. Granite from the lower part of Ben Nevis, and some chips of the over-lying dark porphyritic felstone derived from it.

5. Chips of acid lavas, both vesicular and compact, from the neighbourhood of Oban.

No. VII.—Notes on Tarbert, Argyllshire. By James White.

[Read 15th October, 1885.]

That quiet little nook Tarbert on Loch Fyne, familiar I have no doubt to many of the members, was to me a *terra incognita*, so I thought I would spend a short holiday there, and with hammer in hand try to pick up some acquaintance with it. In the hope that there may be something to interest others, as I found a good deal to interest myself, I purpose to give some account of what I observed of the rocks round Tarbert.

Among those arbitrary divisions called counties, that of Argyll presents features which are probably unique in Scotland. It has been described as "a congeries of mountains cloven with glens." No part of it is more than twelve miles from the sea. Its outlines are so exceedingly irregular, the projections of mainland into the ocean so bold, its intersections by sea-lochs so numerous and extensive, and the distribution everywhere of land and water so

intricate, that perhaps no equal extent of country in the world contains so rich and varied a display of landscape.

With an area of 3,255 square miles, its weather-beaten, deeply-indented shores present to the sea a coast line of no fewer than 2,289 miles. It includes eleven arms of the sea, measuring from two or three to thirty-six miles in length, and two of them exceeding in parts the 100-fathom line in depth. There are, besides, numerous valleys which, though now inland and occupied by fresh-water lakes, were evidently at a recent period arms of the sea; and these represent a further line of coast 276 miles in extent. In short, we have here a tract of country which presents features of exceptional interest to a student of physical geology.

The peninsula of Kintyre is the principal of several tongues of land into which this county is broken up, and is about 60 miles in length from where it joins the mainland at Crinan to its most southernly point, "The Mull." The Kintyre district proper, 43 miles in length, terminates at Tarbert. The northern part of the peninsula, between Tarbert and Crinan, is the district of Knapdale, 17 miles long: the average breadth over the whole peninsula is 8½ miles. It is deeply cut into by several sea-lochs, principally on its west side, all of which an elevation of 300 feet would convert into land valleys. It is at the head of one of these small lochs, and on the east side, that our destination lies.

East Loch Tarbert is separated from West Loch Tarbert by a neck of land of no great elevation, and very little more than a mile in breadth. This, nevertheless, forms the watershed between the two lochs, from which burns descend into each of them. This isthmus it has been proposed to cut through, and connect the two lochs by means of a canal, enabling vessels to avoid the circuitous route by "The Mull." A bill for this purpose was passed through Parliament in 1883, but nothing further has yet been accomplished.

The East Loch is scarcely a mile long. At its upper end, next the town, it broadens out into a bay, giving it roughly the outline of a reversed letter L. It is studded with small islets, which give it the intricate and scraggy look it has from Loch Fyne.

The West Loch runs N.E. to S.W., and is 10 miles long, with a mean breadth of three-quarters of a mile. It has an aspect of a totally different character from the East Loch. The rocks on its banks show nothing of that gnarled, scraggy appearance so

characteristic of the East Loch. It has been described as having the appearance of a fresh-water lake rather than an arm of the sea; "soft and moderately high hills recede from its margin, and woods and enclosures fling their images upon its waters."

The village of East Tarbert seems to be mostly new, and is evidently increasing very rapidly. Herring fishing and the accommodation of strangers are the sole industries. The Fisheries Commission have a station on the north side of the loch, which is under the charge of an esteemed member of this Society, Mr. Scott, late of Greenock.

The rocks in the immediate neighbourhood of Tarbert are of that gnarled, contorted, schistose character with which we are so familiar in the greater part of the Highlands, and notably in that part which has received the grotesque appellation of "Argyll's Bowling Green." They contain numerous lenticular masses and veins of quartz, and sometimes assume quite a chloritic character. They are designated "quartz-schists," from their containing so much of that mineral. They evidently vary much in their composition, and weather out into the most irregular and striking forms. We everywhere see that their gnarled asperities have ante-dated the "great ice-age," and have lived through it; for, whilst it has left upon their contours its unmistakable marks, it has been quite ineffectual to change their aspect.

I had the good fortune to meet in Tarbert Mr. Hill, an officer of the Survey, who had spent some time in examining these rocks, and he informed me that as far south as Skipness he had been able to detect nothing else. The distance from Tarbert to Skipness in a straight line is about 7 miles, though by the road it is 12. The lie of the coast at this part is N. by W. to S. by E. The strike of the rocks is N.E. to S.W.; the dip is "everything by turns and nothing long"—for the most part it seems vertical. If they were vertical throughout, we would have here represented a very great thickness of strata, probably over 20,000 feet.

The map shows that at Skipness they dip to the S.E., and at Ardrishaig to the N.W. It thus appears that these two lochs of East and West Tarbert run along, and have been eroded out of, the crest of an anticlinal axis. Nothing could more effectually illustrate the fact that the surface configuration of the country is due to epigene agencies, or more strikingly show the amount of change which it has undergone.

To the north and west the strata become much more varied in

character. In walking along the road, which runs pretty close to the shore from Tarbert to Ardrishaig, a distance of 11½ miles, we meet with beds of limestone and sandstone, also volcanic rocks of a distinctly basic character. About 2 miles down the Campbeltown road there is a small quarry to the right opened up for road metal, in which three different kinds of stone occur—(1) A bed of limestone about 18 inches thick, standing vertical; (2) alongside of it, a bed of hornblende schist; and (3) cutting them both at right angles, a dyke of unusually fine-grained basalt. The hornblende schist Mr. Hill regards as an intrusive igneous rock, meaning, not that it was intruded amongst these rocks in its present condition and as they at present stand, and might therefore be fairly considered as a trap dyke (of which there are some in the neighbourhood, differing in no way from the normal crystalline condition of dolerite), but that it was intruded amongst them in the condition of a dolerite, and as a horizontal sheet, and that it has been tilted and crushed along with them. The evidence of this intrusion consists in the great alteration which is effected in the limestone where they come into contact. Similar features have been observed in other localities in the neighbourhood, where the greenstones had altered the sandstones with which they had come into contact into quartzite, and had themselves subsequently passed into hornblende schists. [Specimens were laid on the table illustrating these changes.]

This is a point of some interest, and one which I have not seen noted in any text-book. Schists are usually regarded as metamorphosed sedimentary rocks, which, from being soft and pulpy mud, have by heat and pressure been partially melted and pressed out into schistose splintery form. Every gradation in this process can be traced, from quite unaltered sediments to the most schistose or slaty, and even to a crystalline condition. But it is of interest to note that this process can sometimes be reversed, and that by a re-fusion of a crystalline rock and by pressure it can be made to assume the character of a schist. Mr. Teale, *Quarterly Journal Geol. Soc.*, May, 1885, describes a reversion of this kind which he had traced in a dyke of dolerite near the village of Scourie in Sutherlandshire, and which he illustrates with a drawing of the rock, showing the transition from the granular to the foliated structure, and also with microscopic sections.*

* Mr. Hill mentioned that he had traced a similar reversion in granite rocks, of which he had considerable experience, having been previously stationed in Cornwall.

Two miles farther on the same road, in a field to the right, there has been opened up another bed of limestone which is estimated to be about 40 feet in thickness, but not being of good quality the working has been abandoned.

Two miles north, on the road to Ardrishaig, in a wood to the left, another bed of limestone occurs, and is at present being worked. About 15 feet of it is exposed, and it is very crystalline in texture. In none of these limestones have any fossils been met with. Farther on, a bed of very fine-grained, highly-indurated sandstone has been opened up for road metal; it is largely charged with iron, and gives to the roads quite a bricky appearance. (Specimens shown.)

As we approach Ardrishaig, we come to what is indicated on the map as a higher horizon of strata, and begin to see the north-western dip of the rocks, and also the intrusive volcanic rocks which are there indicated. The chips of volcanic rocks which I got there are of the usual crystalline character; it is nearer Tarbert—nearer to the centre of the anticlinal axis, where the greatest pressure must have occurred—that they assume the character of hornblende schist.

Geological Age.—These rocks are all assigned to the Lower Silurian period. This was Murchison's famous generalization, with which, probably more than anything else, his name is associated. From the first, however, it did not receive the unanimous consent of geologists to all the extent which Murchison claimed for it. Sedgwick fought most stubbornly the battle for *Cambrian*. Prof. Lapworth and others regard its several horizons as being sufficiently distinct to merit distinct names, and have suggested the terms "Ordovician," "Dimetian," etc., as being more appropriate for the districts or groups which they represent; whilst the recent revolution in our knowledge of Highland stratigraphy seems to throw suspicion on all the knowledge hitherto acquired on this subject, confessedly one of the most difficult in the whole range of the science.*

For wide districts there appears to be no such thing as a "system" or "formation"; the apparent base of a formation in one place is not the base in another, and the boundaries are perpetually open to dispute. Such terms are true only for limited

* See *Nature*, 13th Nov., 1884, vol. xxxi., p. 29. Also Dr. A. Geikie's "Text Book," 2nd edition, 1885, p. 574.

areas, and are at all times subject to modification by further discovery. All we need say at present is that these strata, by whatever name they may be called, are evidently all older than the Old Red Sandstone.

Glacial Phenomena.—The glaciation of this district has been from the N.E. It is chiefly seen in the rounded form which its innumerable projecting masses assume, all of which show their abrupt faces to the S.W. I ascended the hills on the south side of Tarbert fully 1,000 feet, and everywhere the same features presented themselves. As in Bute and many other places, the smoothing agent evidently travelled *across* the peninsula. Boulder clay occurs only in very small patches. The perched blocks are all of a schistose character.

No. VIII.—Notes on the Geology of Oban. By Dugald Bell, Vice-President.

[Partly read 10th January, 1884.]

In going northward to Oban a geologist's first impression is that he has passed over a great anticlinal axis, on the other side of which he finds repeated over again the same strata as he had previously seen. Thus, crossing the Old Red Sandstone and its conglomerate at Balmaha on Loch Lomond, and at the opening of the Firth of Clyde near Cardross, and leaving the clay-slate which appears at Luss, Rosneath, Inellan, and Bute, he enters upon a tract of mica-slate and other varieties of schistose and quartzose rocks extending along Loch Fyne, the Crinan Canal, and the western coast of Knapdale. Then at Easdale he comes on the clay-slate again, and immediately after, along the Sound of Kerrera onwards to Oban, he sees a well-marked conglomerate, which he is apt to take as, of course, the Old Red conglomerate resting on the clay-slate of the district as before. A further examination, however, will probably show that this conclusion is by no means certain, and that from the way in which patches and detached areas of newer formations occur in the immediate proximity of the old slate rocks all along

this western coast, the determination of the true age of this conglomerate may be attended with considerable difficulty.

The conglomerate is covered over by great sheets of trap rock which extend eastward to the Pass of Brander, and southward to near Loch Melfort, forming that expanse of lochan-dotted heather-land known as the Lechan Muir. In the neighbourhood of Oban the relative position of the rocks is sometimes very confused—the slate here and there rising into knolls and ridges apparently above the conglomerate, and the trap sometimes, even at lower levels, resting directly on the slate, indicating, evidently, great inequalities in the surface on which both the conglomerate and trap were originally laid down; and also, no doubt, much subsequent faulting and denudation. On the whole, however, the succession manifestly is—slate overlaid by a massive conglomerate, and that again by wide-spreading sheets of igneous rock. The slate is not at present in dispute; but, regarding the age of the conglomerate and the trap, there has been much diversity of opinion.

In this paper we propose to review briefly the various conclusions which geologists have arrived at regarding the age of these Oban rocks. Perhaps such a survey may be useful as a geological study, and may incite some one who has the time and opportunity to collect, if possible, the further evidence which seems still to be required on the subject.

I. Dr. John Macculloch, that industrious pioneer in Scottish geology, who did a wonderful amount of work in his time, and whose observations are being followed with increased respect at the present day, referred to these rocks generally in his description of the island of Kerrera ("Western Isles," vol. ii., p. 110). He began with the "argillaceous schist" as the lowest rock; then noticed a slaty breccia which is found overlying it in some places. Next in order he placed the sandstone and conglomerate, remarking on the great variety of substances imbedded in the conglomerate, and particularly the number of pebbles of the various trap rocks. Lastly, he mentioned the trap "which if not absolutely always uppermost, presents sufficient indications of its posteriority to all the other rocks." He thought there must have been "two distinct formations of trap, one prior to the deposition of the conglomerate, and one posterior; the former being the source of the fragments it contains, and the other now overlying and intersecting the beds." Numerous veins found here and in other parts of

the coast and islands he regarded as proofs of a third period of volcanic action.

The sandstone series he considered as "analogous to that which in other parts of this country separates the primary from the secondary strata"—that is, to what is commonly called the Old Red, though he admitted that it differs from the sandstone usually found in that position, in its broken and interrupted character, and in the nature of its materials. These, however, he accounted for by its having been formed in the immediate vicinity of trap rocks.

II. When Hugh Miller visited the locality in the course of his "Summer Rambles to the Hebrides," now more than thirty years ago, he made no doubt about this being his "ancient friend, the Old Red conglomerate." Having observed how it lies "unconformably along the edges of the clay-slate, which present under it an appearance exactly similar to that which they exhibit under the rolled stones and shingle of the neighbouring shore," he was moved to even unwonted eloquence by the thought that "in the incalculably remote period in which the conglomerate base of the Old Red Sandstone was formed, the clay-slate of the district had been exactly the same sort of rock that it is now. Quarries might have been opened in this rock, as now, for a roofing slate, had there been quarriers to open them or houses to roof over; it was in every respect as ancient a looking stone then as in the present late age of the world." ("Cruise of the Betsey," p. 6.) Assuming the conglomerate to be Old Red, this fact is doubtless sufficiently striking as proving the far greater antiquity of the slate, and the changes that had passed over it before the conglomerate was laid down. But, of course, this unconformity and these changes do not of themselves prove the conglomerate to be Old Red. Indeed, the greater the unconformity between the slate and the conglomerate, and the more striking the changes which the former can be shown to have undergone before the latter was laid down upon it, the stronger, we may say, requires to be the proof that the conglomerate really belongs to the Old Red, and not to a later formation. From the great size of the boulders imbedded in the conglomerate, particularly in the Dog-Stone of Dunolly, Miller argued ingeniously in favour of its high antiquity—that when it was formed this shore was exposed to the full sweep of the Atlantic waves, before Mull and Kerrera acted as breakwaters. But there are so many ways in which conglomerate may be formed—by torrents

and ice, as well as by the sea—and so many "accidents," if we may so speak, by which large blocks may get into conglomerate, that we hesitate to accept this as conclusive.

III. The late Professor Nicol, of Aberdeen, whose views on the geology of the Highlands generally have lately been confirmed in a remarkable degree, placed these rocks in the Permian or Trias, or perhaps even a later formation. In his "Guide to the Geology of Scotland" (1844), referring to MacCulloch's view of there being two or three distinct formations of trap, he wrote—"It may, however, be observed that the age of this sandstone is altogether uncertain, and that the trap may have occupied a long period in its formation." But in the "Explanatory Note" to his "Geological Map of Scotland" (1858), he ventured on a more definite opinion. "In this group," he said, speaking of the Permian and Trias, "I am disposed to place the conglomerates and red sandstones near Oban, almost entirely made up of the detritus of trap-rocks. Resting unconformably on the clay-slates, and covered over by trap, they furnish no very certain marks of the period when they were formed; but they are evidently more closely connected with the Lias of Mull and the Trias of the North of Ireland than with the Old Red Sandstone in other parts of Scotland."

IV. Dr. A. Geikie, after first assigning it to the Oolite and then to the upper Old Red (see Geological Maps of Scotland, 1861 and 1876 *), now inclines to the lower Old Red as the true age of this Lorne conglomerate. In token of this he has named from it one of his "lakes," those great inland waters—Lake *Orcadie*, Lake *Caledonia*, Lake *Lorne*, and Lake *Cheviot*—in which he believes the Old Red in Scotland was deposited. But Dr. Geikie's exposition of the subject is still incomplete. The paper to the Royal Society of Edinburgh, 1879, in which he marked out these four separate areas of deposition, dealt in detail with only the first, namely, Lake Orcadie, and the reasons for assigning this Lorne conglomerate to the lower Old Red have not yet been given

* Professor Judd, in his paper in the *Quar. Jour. Geol. Soc.*, vol. xxx., to which we shall again refer, states that "in the map of Scotland published in 1861 by Sir R. Murchison and Professor Geikie the 'traps' of Lorn are indicated as being of Old Red Sandstone age." This is a mistake. In the map referred to these traps are both coloured and lettered as of *Oolitic* age. In Professor Geikie's map of 1876, however, they are coloured and lettered as belonging to the *upper* Old Red. More recently Professor Geikie adopted the view that they are lower Old Red.

to the world. In his recently published "Text-Book," Dr. Geikie names Lake Lorne as one of the minor areas of the lower Old Red Sandstone, and says it "occupied a basin on the flanks of the south-west Highlands which is now partly marked by the terraced volcanic hills of Lorne." He alludes at some length to the organic remains found in the Old Red of the central and northern basins; but nothing of the kind is adduced from the other two, *Cheviot* and *Lorne*. He merely remarks that in them "volcanic action continued long vigorous, and produced thick piles of lava, like those of Lake Caledonia." (Second edition, pp. 712-714.)

V. Professor Judd, whose researches among both the igneous and the sedimentary rocks of the Western Highlands have added so much to our knowledge of the geology of these regions, in the second of his valuable papers on "The Secondary Rocks of Scotland," discusses at some length the "age of the volcanic series of Lorne."* In the absence of palæontological evidence, he says "the question must be admitted to be still to a certain extent an open one." But he enumerates some "facts to guide us" in forming a judgment concerning it, and these, with all respect, we shall now consider. They are—

(1) "The very marked unconformity between these rocks and the strata of lower Silurian age on which they lie." This, of course, proves that the conglomerate is more recent than the slate, but, we need hardly remark, does not of itself determine *how much* more recent it is.

(2) "The fact that the Mesozoic strata appear to rest upon them [*i.e.*, upon these Oban rocks], and in some instances at least quite unconformably." This would be important if clearly made out, but it is stated so doubtfully that it seems impossible to rest much upon it.

"The only point," says the Professor in a previous page, "at which the series of rocks so well displayed in Lorne is seen in juxtaposition with the Mesozoic sedimentary rocks and the Tertiary lavas is in the south-eastern part of Mull. Here, unfortunately, among the wonderfully disturbed and greatly metamorphosed rocks I have sought in vain for any simple section illustrating the relations of these three series of deposits. Nevertheless, after carefully tracing the positions of such masses as can be reached and studied, there appears to be no room for doubt that the various members

* *Quar. Jour. Geol. Soc.*, vol. xxx. (1874), p. 287.

of the Mesozoic series rest indifferently upon the denuded lavas of Lorne and the older rocks." (P. 282.)

With the greatest deference to Professor Judd's own opinion, we think it evident from the guarded manner in which he expresses it, that he does not regard the evidence under this head as quite clear or conclusive.

(3) The third "fact" the Professor adduces is "the resemblance which the lava streams, of which they [the Lorne rocks] are so largely composed, present in their petrological characters to others on the south of the Grampians, which sometimes alternate with strata containing fishes of Old Red Sandstone species." This argument from resemblance was probably of more weight to geologists some twelve or fourteen years ago than it is now. At that time it was generally supposed that the age of volcanic rocks might be determined, or inferred with some degree of certainty, from their general appearance and characteristics, whether they were acid or basic, more or less crystalline, etc. But since then the conclusions to which those who have specially investigated the subject have been led point very much in the opposite direction. It is now held by such authorities that the resemblance between Palæozoic traps and those of Tertiary age "is often so great that they cannot be distinguished from each other"; and that "difference in geological age is not accompanied by difference in composition and structure." * Or, as Professor Judd himself has more recently expressed it, the differences between igneous rocks "are not to be accounted for by a difference of geological age, but are a consequence of the diverse conditions under which the rocks had consolidated." † Further, in some parts Tertiary volcanic rocks have undergone such changes that they "are in no way distinguishable from the amygdaloidal melaphyres and similar rocks which have usually been regarded as characteristic of the older geological periods." ‡ If this be so, it would seem that, without the proof afforded by their relations to sedimentary rocks, whose age on palæontological evidence is undoubted, to determine the age of

* See a very interesting paper by S. Allport on "The Microscopic Structure and Composition of British Carboniferous Dolerites," in the same vol. of the *Quar. Jour.* as that in which Professor Judd's paper appears, viz., vol. xxx., p. 529.

† *Quar. Jour. Geol. Soc.*, vol. xlii. (1886), p. 50.

‡ *Ib.*, p. 84.

igneous rocks by general appearances, characteristics, or "resemblances," is an entirely hopeless task.*

On the whole it may be said that the only direct evidence yet adduced as to the age of these Oban rocks is that afforded by the somewhat doubtful appearances presented on the south-eastern coast of Mull, as to which we have already noted Professor Judd speaks with much hesitation and reserve. He concludes in favour of regarding the volcanic and associated rocks of Lorne as "belonging to some part of the Newer Palæozoic periods," adding that "to hazard any closer approximation to their age would probably be unsafe."

VI. In Professor Blackie's delightful book, entitled "Altavona," there is a graphic sketch of the geology of the Oban district, in the shape of a lecture given after a pic-nic at Gylen Castle to the highly-favoured company there assembled. The lecturer is represented to be "Hilarius," one of H.M. Inspectors of Schools, and "most ubiquitous of mortals"; a description from which some readers will profess they can easily identify the lecturer. But we are always disposed in such cases to respect an author's *incognito*, and will only say he is evidently one who loves the Highlands and knows them well. "Hilarius" adopts and sets forth Dr. A. Geikie's view as to the Old Red age of these conglomerates and associated lavas, but with some modifications of his own. The conglomerate, he states, was laid down in the depths of that "ancient Old Red loch," Lake Lorne. "Moreover, in the greater part of Kerrera here, and between the Firth of Lorne and Loch Awe there stretch broad deposits of volcanic rock which various indications prove to have been thrown out during the Old Red era." Then, certain dykes of basalt and porphyry which intersect the slates but not the conglomerate "are probably extensions of the great volcanic beds of the Lechan Muir," and so the conclusion is reached that "these beds also existed before the conglomerate was laid down, resting on them, as it also does in some sections." ("Altavona," pp. 131-133.)

* "Many difficulties remain yet to be explained before our knowledge of volcanic action can be regarded as more than rudimentary. Why should two neighbouring vents sometimes eject, the one acid, the other basic lavas? Why should even the same vent occasionally exhibit an alternation of acid and basic eruptions? To these and other questions in the mechanism of volcanoes no satisfactory answers have yet been given." Dr. A. Geikie: "Text Book," 2nd ed., p. 250.

Now, we should suppose, few men can state a geological problem more clearly than "Hilarius," but here we confess ourselves unable to follow him. Granting that there are older dykes intersecting the slates which do not penetrate the conglomerate (and which are to be carefully distinguished from the more recent dykes which intersect slates, conglomerate, and in some instances volcanic beds, all alike)—it seems impossible that these older dykes can be extensions of the volcanic beds of the Lechan Muir. Why? Because the conglomerate comes in between them. Nay, says "Hilarius," it rests on the volcanic beds, at least "in some sections." Well, whatever intermixtures of volcanic rocks with the conglomerate may in some parts be observed, we had thought it beyond dispute that the broad tract of volcanic rocks forming the Lechan Muir *overlies* the conglomerate. We might refer again to the observations of the geologists already named, who all agree in this. But let any one look at the sections exposed along the shore and in the neighbourhood of Oban for himself. And if there still be any doubt on the point, then a distinct reference to the sections which are said to show the conglomerate resting on these volcanic beds would be valuable, and save much time.*

But, allowing for the moment that the fact be as now stated, what light does it throw on the alleged Old Red age of the conglomerate? "No light, but rather darkness visible." For, if the volcanic beds of Lechan Muir be "proved by various indications" to be of Old Red age, and if the conglomerate rests upon these beds, then (without troubling ourselves about the dykes, which after all only result in a probability) we are led straight to the conclusion that the conglomerate is *newer* than the Old Red. Or, to be quite exact, it is at least newer than some portions of the Old Red, and for aught that appears, may be newer, much newer, than any portion of it. Certainly as regards "proof" of either the volcanic beds or the conglomerate being of Old Red

* Professor Judd gives several sections showing the trap resting indifferently on the slate or on the conglomerate, but not one showing the conglomerate resting on the trap. And he says expressly—"The sandstones and conglomerates appear to be wholly confined to the *lower* part of the volcanic series of Lorne. In its upper part, that series consists of stream after stream of lava piled one upon the other in almost endless succession; and, so far as I have observed, these include between them no stratified deposits."—*Quar. Jour. Geol. Soc.*, vol. xxx., p. 285.

age, this interesting lecture at Gylen Castle leaves us very much where it found us—"no forrarder." *

It thus appears that the age of these Oban rocks is still undecided—still, as Professor Judd has said, "an open question"—no evidence on the subject that can be regarded as at all conclusive having yet been adduced.

We may now add a few miscellaneous notes on this much-debated conglomerate and its surroundings. First, with regard to its *composition*. That it is mainly formed of the detritus of trap rocks is a point on which all observers are agreed. There are scattered throughout the mass, in some parts more plentifully than in others, pebbles of yellow and white quartz, together with fragments of various kinds of schistose rocks, and also, according to some observers, of granite. But its distinguishing characteristic is the great number and variety of trap rocks—in masses large and small, some, indeed, of very great size—which it contains. Macculloch regarded it as in this respect different from any other conglomerate which he had seen in Scotland, and instances among the contents "basalt, greenstone, amygdaloids, cavernous trap, and clinkstone, or compact felspar; together with those porphyritic or other modifications that are found associated with the rocks of this extensive family." † There have been changes in the nomenclature since his day, but these do not affect his observation of the number of different kinds of these rocks imbedded in this conglomerate. Nicol describes it in similar terms.‡ Hugh Miller—though, as we have seen, prejudging it to be Old Red—also took notice of the great variety of these imbedded pebbles of trap, and particularly of the fact that many of them "seem identical in their composition with rocks of the trap family, which in other

* It is only right to add that the esteemed lecturer is understood to have since modified in some respects the views on these rocks set forth in the work referred to. We believe he may now be taken as concurring in the opinion expressed in another paper in the present volume (p. 73), to the effect that while the conglomerate belongs to "the ancient Lake Lorne of Old Red times," the age of the trap region behind Oban "still requires final determination." But if the conglomerate belongs to the same series as the trap, and especially if it belongs to the upper part of that series, *its* age must require "final determination" also.

† "Western Isles," vol. ii., p. 117.

‡ "Geol. of Scotland," p. 158.

parts of the country we find referred to much later eras. There occur," he added, "in this deposit rolled pebbles of a basalt which in the neighbourhood of Edinburgh would be deemed considerably more modern than the times of the Mountain Limestone, and in the Isle of Skye considerably more modern than the times of the Oolite." *

Not only the larger contents of the conglomerate, but also its finer portions—the base or matrix in which these masses are imbedded, and the bands or lenticular patches of stratified material interspersed through it—seem to be chiefly composed of the waste and washings of the igneous rocks. These interbedded layers vary in colour and texture from fine reddish bands to a coarse-grained grey or brownish sandstone; but these seem to be merely local varieties, without any definite order of succession; and both alike appear to derive their material chiefly from the waste of volcanic rocks.

As to the condition of the various imbedded masses, they are generally well-rounded, indicating that they must have been subjected for a considerable period to the action of running water, or more probably of waves. No marks of glaciation have yet been observed upon any of them; but we must not hasten to conclude from such negative evidence that some former ice age may not have had to do with the formation of this conglomerate.

This preponderance of trappean material, and the great size of many of the masses imbedded in the deposit, render it extremely probable that the whole was brought from no great distance,—that the tract of volcanic rocks from which the component parts were mainly derived was situated in the immediate neighbourhood. Looking to the admixture of coarser and finer materials, the likelihood is that they were brought down by torrents to the shore either of the sea or some lake, where they were afterwards subjected to the attrition of the waves. †

* "Cruise of the Betsey," p. 9.

† We are inclined to say the *sea* shore, not forgetting the "lake theory," but because we cannot help thinking it exceedingly improbable that such accumulations of well-rounded material should be found on the shores, not to say "in the depths," of any inland lake. We have often been struck with the scanty amount of rounded shingle on the shores of all the inland lakes we know. Nor do we think that torrents or floods, caused by the sudden melting of snow, etc., could of themselves produce such heaps of rounded stones of all sizes as are here brought together. To give rise to

Professor Judd is of opinion that the series was "accumulated along the flanks of a range of lofty volcanoes, the heaping up of conglomerates by mountain torrents, and the outpouring of lava-streams, under which these were buried and preserved, going on side by side." This agrees also with the "local and irregular character" of the conglomerate, which seems to have been accumulated in certain deltas, as fan-shaped masses of alluvium are formed by mountain streams at the present day.*

On the assumption that the conglomerate is of Old Red age, the first and most obvious conclusion is that the abundant and varied fragments of igneous rock which it contains were derived from the older (Silurian or Cambrian) formations. In the words of Macculloch, "it follows that the fragments of trap existing in this rock have, like the other substances, been derived from previous masses of that rock of a date prior to the deposition of the secondary strata, and equally, therefore, to be ranked with the other primary strata, by the fragments of which it is accompanied." Macculloch, however, saw and expressed the difficulty this conclusion involves, for he added that, as may be deduced from many parts of his work, "the trap rocks are usually associated with the secondary strata, and are, in by far the predominant examples,

anything like the contents of this conglomerate, the ceaseless action of the sea, and the sweep of its powerful waves, seem indispensable.

[Since the above was in type some interesting observations on the formation of grits and sandstones have appeared in Prof. Bonney's Opening Address to the Geological Section of the British Association for the present year. This eminent geologist lays it down as a principle that "pebbles indicate the action either of waves of the sea, or of strong currents, marine or fluviatile." In a note he adds—"The waves of lakes also have some rounding effect, but this—except in the case of very large lakes, such as Lake Superior—is not important; and such cases are, of course, not of common occurrence." At the same time he thinks it "probable that a thick and very widely-extended pebble bed is not the result of wave action," seeing that "the zone in the sea over which the manufacture of pebbles can be carried on is generally a very narrow one." Beds of gravel and coarse sand, of considerable vertical thickness and great extension, he considers most likely indicate river action (*Nature*, 9th Sept., 1886). How far this applies to such comparatively local deposits as the Oban conglomerate, with the large-sized rounded masses imbedded in it, may be a question.]

* See *Quar. Jour. Geol. Soc.*, vol. xxx., p. 286.

superior to them; while the instances in which they occur in union with, or immediate superposition to, the primary, are comparatively rare." * Notwithstanding the advance of geological knowledge since his day, particularly as regards the older Palæozoic rocks, then called "primary," we may still take this statement as correct, so far as our own country is concerned. Although there are abundant evidences of volcanic action during Cambrian and lower Silurian periods, in the North of England, in Wales, and the South of Ireland, these are "comparatively rare, if not, indeed, entirely awanting in the corresponding formations in Scotland." † Of course, we do not here refer to intrusive dykes, which may be, and can generally be shown to be, of much later age.

This difficulty is perhaps obviated in some degree by supposing that the fragments of igneous rock in the conglomerate, the conglomerate itself, and the overlying volcanic beds, all belong to one period, namely, the Old Red, and indicate different phases of a prolonged volcanic activity during that epoch. According to this theory, the earlier lava-flows were succeeded by a time of powerful denudation, during which they were broken up and waterworn, and heaped together into this conglomerate; and then followed a time of renewed and greater volcanic activity—greater at least in relation to the denuding agencies—when the overlying beds of igneous rock, still so massive and continuous, were laid down. Whether the great variety of trap rocks imbedded in the conglomerate, to which we have referred, and which seems to be sufficiently well attested, does not still present a difficulty in regarding the deposit as of Old Red age, we must leave to others more competent to determine. We merely remark that, according to this view, there must have been a range of "lofty volcanoes" in the neighbourhood of Lorne during the Old Red Sandstone epoch; and the question arises, Apart from this conglomerate itself, which is in dispute, are there any collateral or independent proofs of the existence of such volcanoes in this neighbourhood at that time?

The interbedded volcanic rocks of the Old Red in other parts of the country occur "several thousand feet above the base of the

* "Western Isles," vol. ii., p. 120.

† "No very distinct traces of contemporaneous volcanic activity have yet been detected among rocks of that [Silurian] age in Scotland."—Jukes and Geikie's "Manual" (1872), p. 561.

system," and are "succeeded by thousands of feet of sandstones, shales, and conglomerates, without any intercalation of lava or tuff." * Here it is remarkable that, both beneath and above the volcanic rocks, there is, so far as yet observed, a total absence of any such strata.

Again, in a survey of the volcanic rocks of our country, we find "there are indications that the eruptions were apt to occur along lines of broad valley." The long depression between the Highlands and the Southern uplands, for example, was "the site of active volcanoes during the Old Red Sandstone and Carboniferous periods"; while "the Tertiary basalts of the north-west lie in a long hollow (at least as old as the Lias) scooped out of the metamorphosed Silurian and Laurentian rocks." † This generalization may be only approximately correct; but whatever weight may be attached to it, it is evident that volcanic rocks in the neighbourhood of Oban are much more in the line of Tertiary volcanic activity than in that of older periods as here laid down.

Though evidently doubtful regarding the age of the Oban conglomerate, and only concluding that it is "analogous" to that which, in other parts of the country, "separates the primary from the secondary rocks," Macculloch certainly regarded the associated and overlying trap rocks as closely related to the adjacent volcanic rocks of Mull, Morven, Ardnamurchan, etc. He speaks of "the general trap district of Mull and Lorne," ‡ holding that "the various disjoined masses have actually been once continuous;" § and, as we have already seen, he had no doubt that these traps are posterior to Secondary strata.

In this connection we may also allude to one of Prof. Judd's later papers, in which he regards that large tract of volcanic rocks extending from Iceland, through the Faroe Isles, St. Kilda, Skye, Eigg, Mull, and other islands, with parts of the adjoining mainland, to the north of Ireland, and including also, he is disposed to think, the island of Arran, as forming "one great petrographical province," the igneous masses of which, "from the most acid to the most basic, and including representatives of every variety of structure, from the most highly crystalline to perfectly vitreous types, are all of post-Cretaceous age." ||

* A. Geikie, "Text Book," 2nd edition, p. 713.
† A. Geikie, *Address to Section C, Brit. Assoc.*, 1867.
‡ *Loc. cit.*, p. 121. § *Ib.*, p. 78.
|| *Quar. Jour. Geol. Soc.*, vol. xlii., p. 58.

We know also, in great part from Professor Judd's own researches, that not only was this tract of volcanic activity an extensive one, but that it was so during a long protracted period. We know that there were intervals of long duration in the action of the volcanic forces, during which beds of soil were formed, and plants and trees took root and grew, and streams hollowed out channels for themselves on the surface of the underlying beds of igneous rocks; all of which were covered over by subsequent lava-flows; and, in short, that the whole of these "piles of ejected materials" were subjected to enormous denudation long before they ceased to receive further accessions from the action of the eruptive forces.

Surely, the proof ought to be strong which requires us to assign this adjacent patch of volcanic rocks, and of conglomerate largely composed of the debris of such rocks, to an entirely different era.

We have alluded to several writers as having stated that the Oban conglomerate contains fragments of granite.* If this be so, it adds some weight to the considerations in favour of the conglomerate being of more recent date than has been so frequently assigned to it. The granite protrusions of our country are generally admitted to be subsequent, many of them evidently long subsequent, to the formation of the Old Red conglomerate.† But as we have not been able by our own observation to confirm this statement, we do no more than mention it, entering at the same time a *caveat* against the *absence* of granite (should this be established) being taken as conclusive on the other side. It may be true that, so far as known, no Old Red conglomerate contains granite; but it does not follow that all other or later conglomerates must contain it.

Another circumstance that may be noted is, not only the local and detached character of this conglomerate, but its comparatively undisturbed position—the entire unconformity and disconnection, so to speak, between it and the underlying slate rocks. It differs in this respect from the undoubted Old Red conglomerates in

* *E.g.*, Macculloch, Nicol, and Miller.

† The absence of pebbles of granitic rocks from the conglomerates of the Old Red Sandstone has often been remarked upon, as, for example, with regard to the conglomerate in Arran.

other parts of the country. These, although certainly unconformable to the underlying schists, are yet in every case much disturbed, and tilted up for considerable distances at a high angle, showing unequivocally that great movements of the earth's crust have taken place since their deposition, by which, along with the rocks on either side of them, they have been powerfully affected.*

Taking all these points—more or less important as they may be regarded—into consideration, may we not conclude with Prof. Nicol, that these conglomerates and associated volcanic rocks in the neighbourhood of Oban are more closely connected with the volcanic and sedimentary rocks of Mull and the North of Ireland, than with those of older date in other parts of the kingdom?

At least, I think we are entitled to say that the question as to the age of these rocks requires further investigation; and it is for this reason that I have ventured to bring the subject (at perhaps too great length) before the members of this Society.

The addition of a few local notes, however brief, may still make this paper less incomplete.

On the north side of the bay, towards Dunolly, the slate crops up here and there along the shore, in some parts almost vertical, in others dipping to the north-west. Near the Dunolly gate we find the conglomerate—including numerous bands of sandstone—overlying the slate unconformably, and dipping at a low angle to the south-east. Here it contains many quartz pebbles, but as we follow it towards Dunolly, in the neighbourhood of the Dogstone and farther on, it seems to become more exclusively trappean in character. It is well seen in the wood beside the approach to the Castle, and extends backward about half-way up the hill, where it is succeeded by the volcanic rocks.

Returning to the village, we observe in the street at the head of the quay the strata of slate come to the surface with a northerly dip as before. In the cliff behind the village we can still see a section similar

* Macculloch, with his usual accuracy, notes this irregular local position of the conglomerate as a "circumstance in which this rock differs from that which usually separates the primary and secondary strata." (Vol. ii., p. 117.)

to that described by Hugh Miller—the thick mass of conglomerate resting on the upturned edges of the slate, with at one part a thin bed of breccia between. If we make our way to the top of the hill, beside the unfinished buildings of the Hydropathic Establishment, we find it capped with volcanic rock.

Farther south, as we leave the village by the old Connal road, the slate re-appears in a high cliff overgrown with ivy ; and behind it, to the east, the conglomerate again, with numerous blocks strewn at the foot. Then, a little farther on, we come once more to the trap, in which a large quarry is wrought.

We are now in what may be called the "old bay" of Oban—the bay that was occupied by the sea before the "last elevation" of the land, and which extends a considerable distance inland from the line of the present bay and harbour. The railway sweeps along the southern side of it, gradually rising to the undulating heights of the Lechan Muir.

There has evidently been much denudation here, and it is not easy in some places to make out the true relations of the rocks.

At one part the conglomerate rises in a large knoll or hillock, which in all likelihood formed an island near the head of the old bay. In this "island," as in some of the sections seen along the shore, the lower portions are of finer material, forming sandstone, and the upper portions more conglomeratic in character.

Coming down to the railway, the first deep cutting after leaving the station is through the slate, in which a large quarry is wrought immediately adjoining. The strata here are much contorted, and are intersected with a number of quartz veins. A few hundred yards farther on, the line cuts through a knoll of trap-rock resting directly on the slate. The section shows about twenty feet of rudely columnar trap, with the slate beneath, a good deal altered by contact with the igneous rock. Near the cutting, a large dyke is seen to intersect the slate in a direction from west to east. North of the quarry, a detached ridge of conglomerate rests on the slate. It is chiefly trappean in its composition—not much, if any, quartz or schist being discernible.

On the south side of the bay we see at several points the strata of slate on the shore ; the old sea-cliff of conglomerate, assuming many picturesque and sometimes fantastic forms, rises high beside the road, all the way down to the Kerrera ferry-house ; and over all, as we can easily prove by taking the hill-road on our return, extends the "trap region" of Lorne. But in many parts the relations of these rocks require further elucidation.

In his section along the southern end of the island of Kerrera (*Quar. Jour.*, vol. xxx., p. 284), Prof. Judd shows "lavas of Lorne" resting on slate to the east of the old castle, and resting on sandstone and conglomerate to the left of it. This conglomerate is said to contain "many

pebbles and blocks of the lavas of Lorne," and yet is shown to be covered over by these lavas. Of course, it could not be formed out of the very lavas which overlie it; the explanation adopted being, as stated, that at one period the conditions were such that the lavas were broken up and more or less water-worn, while at a later period they retained their form as continuous sheets of igneous rock.

The conglomerate on which Gylen Castle stands, the Professor notes, is "mainly composed of pebbles and blocks of lower Silurian rocks." He thus apparently makes out *two* conglomerates, or at least two adjacent portions of the same conglomerate, differing considerably from each other. He evidently holds, however, that it is the same conglomerate—some portions being more exclusively trappean, and others containing a larger admixture of schists and quartzes, these varieties being due to local causes, and passing into each other without any discoverable order. Our own impression, given with all deference, from the examination of a good many sections, is that on the whole the lower beds of the conglomerate are chiefly made up of fragments of volcanic rocks, and its higher portions present a greater variety and abundance of other materials.

As showing the confused appearance which in some places these rocks present, and the uncertainty that has existed regarding them, I have annexed, on the opposite page, a copy of Macculloch's ideal section of the island of Kerrera (Fig. i.) and also one of Prof. Judd's section of the same island (Fig. iii.); while in the second diagram (Fig. ii.) I have attempted to fill up Macculloch's outline, so as to make it more intelligible, and show that, notwithstanding the confusion which at first sight it presents, it may yet be taken as corresponding with the sections given by later geologists. (The sandstone in the foreground, though apparently lower in position, of course leans on the schist, and is really superior to it.)

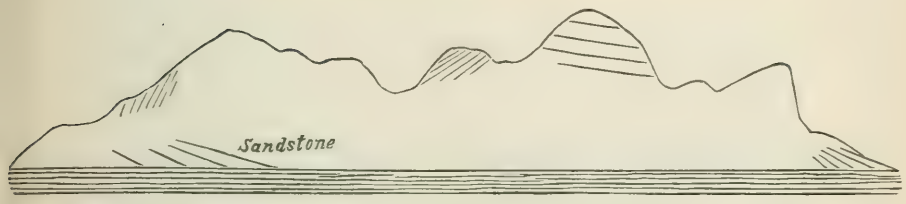
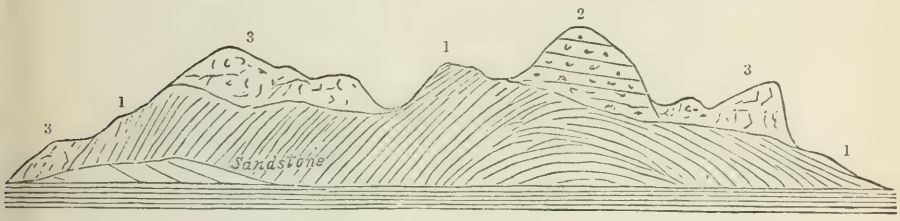


FIG. I.—IDEAL SECTION OF KERRERA (Macculloch).



1. Schist. 2. Conglomerate. 3. Trap.

FIG. II.—MACCULLOCH'S OUTLINE, AS SEEN IN FIG. I.; BUT FILLED UP SO AS TO SHOW THAT IT REALLY CORRESPONDS WITH SECTIONS GIVEN BY LATER OBSERVERS.

a Lower Silurian slates. *b* Breccia composed of angular fragments of *a*. *c* Conglomerates and sandstones. *d* Porphyrite lava-streams. * Slates baked and altered by the enveloping lava.

FIG. III.—SECTION THROUGH THE HIGHEST POINT OF THE ISLAND OF KERRERA, ILLUSTRATING THE RELATIONS BETWEEN THE SLATE ROCKS AND THE OVERLYING VOLCANIC SERIES OF LORNE (Judd).

No. IX.—Note on the Cathkin "Osmund Stone," a Volcanic Tuff. By John Young, F.G.S., *V.P.*, and D. Corse Glen, F.G.S.

Read 16th October, 1884.

In a paper* on the igneous rocks found in the quarries at Cathkin, we referred to the "Osmund stone," described by the Rev. David Ure.† Since his time further operations in the upper quarry have caused the quarrymen to excavate certain portions of the "Osmund stone" which underlies the thick bed of dolerite used for macadamizing purposes. These portions of rock have been laid on one side at the western entrance to the quarry, and on a recent excursion we were able to obtain specimens of its principal varieties, and also to study what we believe to be some of the conditions under which it was erupted. These present many points of interest, and we exhibit five of the principal varieties of the rock, as well as sections for microscopic examination, so as to illustrate the mineral composition of the tuffs. The prevailing colour of the rock is a reddish brown, interstratified with layers of ash of a light greenish grey colour. It is only moderately hard, and under the influence of the weather some of the beds rapidly crumble down into a rough granular clay. In our former paper we stated that this rock was sometimes used industrially, owing to its property of resisting heat, for the paving of oven soles, but it seems now to be less used than formerly for this purpose.

The Cathkin tuffs are evidently portions of extensive beds alternating with the igneous flows of felstone and dolerite which build up these hills, but as there are few natural escarpments where those rocks can be studied it is impossible to say how far any one of the tuff beds extend in the district, or in what directions they thicken or thin away from the points of eruption, which must be located somewhere in the Cathkin hills.

No. 1 is the variety in which the ejected fragments attain their largest size. These vary from one half inch or more in diameter to less than one quarter inch. They are generally angular in shape, and are composed of felstones, red, brown, and purple in tint, which gives the rock a dark colour. The cement-

* *Transactions*, vol. vii., p. 169, 1882.

† *History of Rutherglen and East Kilbride*, 1793.

ing material of the fragments in this variety is partly a volcanic dust, some of the larger interspaces being filled with a later infiltration of white calcite. Olivine crystals are seen in some of the fragments of felstone, but are not so abundant as in some of the other varieties. The deep ferruginous colour seems to be due to a staining of peroxide of iron, probably derived from the decomposition of some of the original iron elements of the rock.

No. 2 is a grey variety of the tuff, banded at intervals with a layer of a reddish brown ash. The fragments entering its composition seldom exceed one-eighth inch in diameter, and in sections under the microscope these are seen to be cemented by a bluish white chalcedony, which, in an agatized form, fills up all the cavities between the rock-fragments. This variety when ground in thin opaque sections, so as to be viewed on both sides under the microscope by reflected light, forms a beautiful object. If a section is ground so as to show the red and grey layers on the alternate sides, we then find an assemblage of various coloured rock fragments, consisting chiefly of felstones. These are of all tints and texture, varying from bright brick-red to reddish brown and purple, and also into greys and whites. Along with these are numerous crystals of olivine, some of which, by subsequent alteration, have given a beautiful greenish tinge to portions of the chalcedony and felspar crystals. The rock, in fact, has by this alteration of the olivine become so far serpentinized, as is seen to be the case with many other igneous rocks in which olivine exists. These olivine crystals in the tuff are easily known by their green colour, but under reflected light there are others which shine with a golden bronze metallic tint. The felstone fragments are sometimes compact, sometimes minutely crystalline, and sometimes minutely vesicular in texture, many of them containing small crystals of iron in an oxidized condition. Altogether this variety forms one of the most interesting and beautiful forms of a volcanic rock which we appear to possess in the West of Scotland. It is one that the eye never tires of looking at, as the sections will bear any amount of enlargement under the microscope and yet never look coarse. The setting of the various coloured felstones and olivines in the bluish white chalcedony looks like a piece of brilliant, miniature, mosaic work under the illumination of the microscope, but it is a piece of work that never could be successfully imitated by the most skilful of human hands.

This volcanic tuff in some of its layers reveals the interesting fact that while being erupted, and ere it fell to the earth, its fragments had so far been assorted by the winds that those which fell over certain areas, and now form certain layers, are of nearly a uniform size of grain. Microscopic sections also reveal the fact that in many of these layers the finer volcanic dust which naturally would have fallen along with the fragments under a still condition of the atmosphere, has been wafted by the winds into other and more distant areas, hence many of these tuffs have been cleaned by a sort of winnowing process, and the interspaces which would otherwise have been filled with fine volcanic dust now contain a later infiltration of chalcedony or calcite. We also think that there is evidence to show that these ashes fell lightly over the earth, and that since they fell they have never been moved by either wind or water from the tracts where they now lie. Had they been moved by either agency evidence would have been seen in the filling up of the interspaces between the fragments by either dust or mud, but such is not the case, for the beds seem to have existed in their open, porous condition until the period when they were permeated by the waters holding the silica and calcite in solution. We may here mention that in the Cathkin quarry silica in the form of a bluish white chalcedony is often found in thin veins or crusts in fissures of the felstones, and also filling up cavities in the vesicular varieties. It has probably been introduced into these rocks at a later period by heated waters holding silica in solution.

No. 3 forms a thin compact band of tuff, which seems originally to have been of a reddish brown colour, and is composed of crystalline and vesicular olivine felstones. It is now, however, curiously mottled, and, in sections examined under the microscope, this is seen to be due to a subsequent discharging of the red colour around the edges, and even to the centres of many of the fragments, which have thereby been bleached under the process into whites and various shades of grey. The agency which has produced this curious appearance has probably been water holding some substance in solution which has acted chemically upon the iron oxides in the rock, but which has not, however, affected in any way the colour of the olivine crystals. This variety of tuff, from its more compact structure than that of No. 2, holds less chalcedony amongst the fragments, and is therefore somewhat

inferior in beauty as an object for the microscope, although the reds of its felstone fragments are more brilliant.

No. 4 is a fine-grained variety of the tuff, in which the fragments are small, and of a dark, purple brown colour, but when seen under the microscope with a good light they become a more brilliant red, and are seen to contain a few olivine crystals scattered about in the matrix. The rock fragments in this variety, although small, appear to have been well cleaned by the wind before they fell from any finer volcanic dust. This is well seen in a section of the rock which we exhibit, and in which the interspaces between the fragments is now filled with a bluish white chalcedony that contrasts strongly with the dark colour of the fragments, and at the same time clearly shows that the tuff previous to its percolation by the chalcedony must have existed in an open porous condition.

No. 5 is from a compact layer in the tuff, in which the grains are small, and the cementing material is a fine volcanic dust that fills up nearly the whole of the interstices, and consequently sections show very little of the white chalcedony so abundantly present in some of the other porous varieties. Hence this is not such a beautiful stone as the others for sectioning purposes. The chief interest in this variety consists in the way in which the red and grey layers of ashes alternate with one another, giving to the rock a fine banded appearance. We think that there can be little doubt but that they represent distinct showers of ash, and probably from the way in which the red and grey layers of ashes alternate in these Cathkin tuffs they may have been erupted from various necks or vents which were not all in activity at one time, and this may account for the varying colours of the rock fragments and their sharp alternations with one another.

Other varieties besides these could easily be collected, but the five exhibited we consider to be the most typically distinct, and to show best the characters under which we believe them to have been formed. Prof. A. Geikie, in his memoir "On the Carboniferous Volcanic Rocks of the Basin of the Firth of Forth,"* when speaking of the fragmental rocks or tuffs, says (page 513)—"The fragmental rocks do not yield such satisfactory results as the crystalline masses to investigation with the microscope." This, he explains, is owing to the volcanic debris commingling with ordi-

* *Trans. Royal Soc. Edin.*, vol. xxix., 1880.

nary mechanical sediment, such as sand or silt, and he shows that in the district under review "we are constantly presented with varying mixtures of fine volcanic debris and ordinary mechanical sediment;" and "where the tuffs occur as beds or laminæ, interstratified with sedimentary rocks, the paste necessarily becomes mixed with the sand, mud, or limestone which may have been gathering on the floor over which the volcanic eruptions took place." The almost entire absence of sand, mud, or other mechanical sediments in the Cathkin tuffs indicate, we think, different conditions of deposition from those described by Professor Geikie, and, as formerly stated, we are inclined to believe that these beds were deposited on land above water, the cementing material of silica and calcite being afterwards carried into the porous tuffs by the slow permeation of waters holding these minerals in solution.

No. X.—Notice of the late Dr. Thomas Davidson, F.R.S., F.G.S., *Honorary Member*. By John Young, F.G.S. *V.P.*

[Read 10th December, 1885.]

I am very sorry to have to ask you this evening to allow me to place upon record the great loss that this Society, and the geological world in general, have sustained in the death, on the 14th October last, in the 69th year of his age, of our highly distinguished honorary member, Dr. Thomas Davidson, F.R.S., of Muirhouse, Midlothian, at his residence, 9 Salisbury Road, West Brighton.

Dr. Davidson was elected the first honorary member of our Society in 1859, the second year of its existence. It was in the year 1856, when he began to gather material for his monograph on the Carboniferous Brachiopoda of the British Isles, that the members first made his acquaintance. Previous to this he had completed between the years 1851 and 1854 the first quarto volume of British Brachiopoda for the Palæontographical Society, comprising the Tertiary and Secondary species. At that time I was residing at Lennoxtown, Campsie, and Dr. Davidson wrote to see if I could assist him by the loan of Scottish Carboniferous Brachiopoda from my own collection, and by giving him the names of other collectors whom I knew to be possessed of specimens.

This I was very willing to do, and the correspondence then opened up only closed with death, his last letter being dated 8th October, 1885, the week before his decease. During this long interval of twenty-nine years very many letters had passed between us, and all relating to his great work above mentioned. It makes me sad to find that of the ten individuals he thanks for assistance in the preface to the Carboniferous monograph, dated June, 1857, and whom he styles his "Scottish friends and countrymen," I am now the only living representative.

After coming to my present post in Glasgow, in 1859, I pressed upon Dr. Davidson the importance of preparing a short descriptive monograph of the Scottish Carboniferous Brachiopoda, with plates, and this he kindly consented to do, having in the meantime been elected an honorary member of our Society, an honour which all his life he highly appreciated.

This monograph of the Carboniferous Brachiopoda of Scotland is a very valuable little work. It appeared in the "Geologist" (now the "Geological Magazine") during the years 1859, 1860, with the following title:—"The Carboniferous System of Scotland, characterized by its Brachiopoda. By Thomas Davidson, F.R.S., F.G.S., Honorary Member of the Geological Society of Glasgow," etc., etc. In the introduction reference is made to the many eminent Scotchmen who have "contributed to elevate the science of Geology to the rank it now holds among all men of learning"; and it further states, that, "Much has however still to be achieved before the geological and palæontological details connected with our country will have been completely worked out." "I therefore hailed with much hope and delight the foundation of a Geological Society in Glasgow, which originated in May, 1858, with about a dozen young men, who wished to gain knowledge of the geological phenomena in the neighbourhood of their great city." "The Society has already done some good work, and increased its numbers to about one hundred." The author further refers to the palæontological riches of some of our rocks, and says—"I here attempt the publication of a special illustrated catalogue or monograph of all the Scottish species of Brachiopoda that have been hitherto obtained from the strata of the Carboniferous period; and this I have undertaken in the hope that by so doing it may stimulate and facilitate further researches, as well as prove of some assistance to those friends in Scotland to whom I am per-

sonally indebted for the gift and loan of the valuable series of specimens which will be made use of in the present memoir."

In the year 1868 he also prepared a quarto paper of twenty-one pages, with three plates of figures, on the "Upper Silurian Brachiopoda from the Pentland Hills." This was printed, and was intended to form the first part of a projected palæontological series on Scottish fossils, to be issued by a committee of members of this Society, but the scheme was never further carried out.

During the long series of years that Dr. Davidson was engaged upon his great work on the Brachiopoda he was a hard worker and methodical investigator, grudging every day that he could not devote to it. He generally worked from six to eight or even ten hours per day, and at one period he wrote me often that he was very much afraid his health and sight would break down from the long-continued strain before he had finished on the stone all the plates for his monograph. The desire to see this great work completed was his constant aim during the later years of his life, and, happily, with care, this wish was accomplished. He had a warm regard for everything Scottish, and often in his letters he expressed a desire to visit "dear old Scotland" more frequently than he was able to do, but it was very seldom that he ever was tempted to tear himself away from his engrossing work. On one of his visits to his estates in Midlothian, he came for a day and night to Glasgow, and was entertained to dinner by members of this Society in one of the hotels of the city. This was in the year 1863 or 1864.

After having finished his series of monographs on the Brachiopoda of the several British formations in 1871, he again returned to the work in a series of supplements, in which he figured, and described, all the additional species or varieties that in the interval had been discovered, or of which better preserved examples had been found. It is in these supplements that he was enabled to do full justice to all that had been discovered in Scotland in the strata of the Carboniferous and Silurian formations, and it is here that was found the full value of the special Carboniferous monograph to which I have already referred, as members of this Society were thereby enabled to add to its list of Scottish Carboniferous Brachiopoda all the later discovered species. In the introduction to his Supplement of Carboniferous forms, p. 249, he states that "eleven other species had been

discovered, described and illustrated, that were either new to science or new to Great Britain." In the same interval of time eight species were added to the Irish list, while none were added to the English.

It gave Dr. Davidson the utmost pleasure to be able to illustrate so many genera and species of Brachiopoda from the Silurian strata of the Girvan district, the result of the careful collecting of Mrs. Robert Gray and others. At p. 220 of his Silurian supplement he sums up all the Scottish species of Brachiopoda which had come under his observation from the several formations, including the Recent period. These are, in all, as follows:—4 Recent, 2 Post-tertiary, 17 Liassic and Oolitic, 59 Carboniferous, and about 134 Silurian species, making a grand total of 216 so termed species. "This," he says, "is a large number from a country that had been so long considered as scarcely fossiliferous in this respect. And when it is borne in mind that it is only from the Jurassic, Carboniferous and Silurian formations that Scottish Brachiopoda have been obtained, the number of species is certainly remarkable."

During the preparation of Dr. Davidson's later supplements he kindly asked me to examine for him the microscopic shell-structure of several of the genera and species of the perforated Brachiopoda from the Carboniferous and Silurian formations. This I did from time to time, and sent him the specimens operated upon, with my notes of remarks. These interested him so much that he has done me the honour of printing in his great work my notes on what I had discovered, and of stating that my researches had revealed in some cases points of structure not formerly known, and in others structures only briefly noticed, and very imperfectly described.

Dr. Davidson completed the last supplement to his series of monographs in 1884, having been nearly thirty-four years engaged on the work. It forms a bibliography of all the papers known to have been written on this group of the Mollusca, from the first notice in 1606 down to the date of the publication, and fills one hundred and sixty-three quarto pages. This bibliography he considered an important piece of work, the materials for which he had been collecting for years, and he told me that as it had cost him a great deal of time and research, he hoped it would be of use to all subsequent investigators of the Brachiopoda by

acquainting them with what had already been written on the subject.

During the long series of years in which Dr. Davidson was engaged in describing and illustrating the fossil Brachiopoda, he at the same time was quietly assembling a collection of the Recent forms from all the seas of the world where they could be obtained. Of all the species of these he had already drawn illustrations ready to be placed on the stone for printing, and had likewise written out the necessary descriptions. They will fill a large quarto volume, which he had arranged, previous to his decease, should be printed for the Linnean Society of London, of which he had long been a distinguished member.

Having stated thus much regarding Dr. Davidson's life-work, and especially his work in connection with the Geological Society of Glasgow, and the Scottish fossil Brachiopoda, I will now only refer those who wish a fuller sketch of his scientific career to an article in the "Geological Magazine" for April, 1871, entitled, "Eminent Living Geologists: Sketch of the Scientific Life of Thomas Davidson, F.R.S., with portrait." In that sketch they will learn that upwards of thirty scientific societies, all over the world, did themselves the honour of placing his name on their list of honorary members. Also, that up to that date, he had written no less than some forty-nine distinct works or papers on the Brachiopoda, which fill some 2,220 pages, accompanied by 244 plates of figures, all drawn and placed on stone ready for the printers by his own hands. Surely such long-continued industry, coupled with so much talent and enthusiasm, may well call forth the highest esteem and admiration for our departed honorary member. I therefore take the liberty of moving, that we as a society instruct our Honorary Secretary to write to Mrs. Davidson and family, expressing our sympathy with them in their bereavement, with the feeling of loss that this and kindred societies have sustained in the death of our lamented friend Dr. Davidson.

No. XI.—Notes on the Carboniferous Brachiopoda of Scotland, with a revised list of the Genera and Species. By John Young, F.G.S., *V.P.*

[Read 11th March, 1886.]

In the present paper I offer a report to the Society on our present knowledge regarding the genera of Carboniferous Brachiopoda found in Scotland, with remarks on their shell-structure and other external and internal characters; also a revised list of the Scottish species, as determined by the late Dr. Davidson and printed in vol. 5, part 3, of his "Monograph of the British Fossil Brachiopoda," for the Palæontographical Society, London, 1884.

During the period of time embraced in the researches of Dr. Davidson, in connection with this monograph, extending from 1851 to 1884, an immense amount of knowledge has been gained not only of the genera and species of the Brachiopoda found within British strata, but likewise of those found in other countries of the world, as well as of those still living in recent seas. In the preface to the first volume of his work, 1853, Dr. Davidson writes thus of the group:—"Of all the species composing the sub-kingdom mollusca, none are, perhaps, more varied, more elegant in shape, or more abundantly distributed than those to which the term Brachiopoda or Palliobranchiata has been applied. They are found in the oldest deposits at present known to contain vestiges of animal life, and have continued to exist, some in similar, but many under different shapes to the existing forms, through the long successive periods which lead to the present time. Their full value to the geologist is consequently very great; and, as they so frequently fall under his hammer where other classes are often but sparingly represented, they must therefore be looked upon as excellent data for the age of the deposit; for, although some few individual forms pass from one stage to the other, the generality are limited to defined horizons."

It was not until 1857 that the British Carboniferous Brachiopoda came to be taken up by Dr. Davidson.* At that time the whole group existed in a state of great confusion and in a badly determined condition both as to genera and species. You will better understand this confusion and multiplication of names from what

* Second volume of the work.

Dr. Davidson states.* "At the time I commenced my researches, about 260 so-termed British Carboniferous species of Brachiopoda had been recorded by different palæontologists; but, after a most searching investigation, I could not conscientiously admit more than about 100 of these, and in order to arrive at such a reduction no small labour was required, nor was I unmindful of the danger palæontologists should guard against in the breaking down of species, which, if injudiciously done, would be as great an evil as that of uselessly multiplying them." He further states, in the same page, that Professor Morris, in his "Catalogue of British Fossils, 1854," had recorded 193 species of Carboniferous Brachiopoda, of which he had retained only 93. Professor Phillips had enumerated 100 species as found in Carboniferous strata in England, of which he had retained only 52; while of 250 species recorded by Professor M'Coy and Mr. Kelly from the same formation in Ireland, he says:—"My most strenuous efforts have not shown the existence of more than about 80."

In Scotland at that time comparatively few Carboniferous Brachiopoda had been recorded. For the British Association meeting at Glasgow in 1855 I prepared a MS. catalogue of the Carboniferous fossils from Western Scotland, then exhibited to the members. In the list of Brachiopoda there were 43 named and 14 unnamed species, in all 57 species. Of the 43 named species only 23 are retained in Dr. Davidson's revised list, the rest being held as only varieties, or have since been more correctly determined to belong to genera and species not then known to have been found in Scotland. During the preparation of Dr. Davidson's monograph of Carboniferous species, and since its completion in the supplementary volume, the list of Scottish species has been very much increased, chiefly through the efforts made by members of this Society, in the careful exploration of all the strata known to yield Brachiopoda and other marine forms; and the revised list now shows † that there have been found in Scotland 59 species and 17 named varieties, several of the latter being now held to be good species, and given as such in the concluding volume of the monograph, 1884. These are now found to belong to 19 distinct genera, instead of some 7 genera, the number amongst which the group was formerly divided. Dr. John J. Bigsby, in his "Thesaurus

* "Carboniferous Brachiopoda," p. 211.

† Carboniferous Brachiopoda, Supplement, pp. 257-261.

Devonico-Carbonarius, 1878," gives a list of the species of Carboniferous Brachiopoda from the various countries of the world recorded up to that date, and numbering 939. Dr. Davidson, in remarking on this list, says* :—"Out of this number I find that some 143 species and a few named varieties have been described by myself from Great Britain. Although the total number of 939 will no doubt have some day to be very considerably reduced, still it will show how numerous and varied were the species of Brachiopoda that lived during the Carboniferous period, and especially so during the deposition of the Limestone series and its accompanying Shales."

In my remarks on the genera of Carboniferous Brachiopoda found in Scotland, I shall follow the arrangement given in Dr. Davidson's revised lists, in which the Tretenterata precede the Clistenterata, these being the two groups into which the Brachiopoda are now arranged by zoologists according to their internal organization.

Tretenterata.

Lingula.—This interesting genus, forming one of the oldest and most persistent types of the Brachiopoda which have descended to us from the earlier fossiliferous formations, is represented in the Carboniferous strata of Scotland by four species, of which only two are common, viz., *L. squamiformis* and *L. mytiloides*. These are found to range from the lower Calciferous sandstone series, up through the several divisions of the limestone strata, into that of the millstone grit and upper coal-measures, while *L. mytiloides* seems to have lived on into Permian times, in which formation it is known as *L. Credneri*. In the purer beds of limestone in the Scottish coal-fields, *Lingula* is rare, but it abounds, especially *L. squamiformis*, in certain of the shales which alternate with the limestone series. In the Glasgow coal-field, in the group of lacustrine strata embracing the lower coals and ironstones which lie between the lower and upper limestones, the two species above-named are often seen to crowd certain horizons of black, carbonaceous shales, having flourished apparently under conditions of water not favourable to the growth and development of any other marine organisms. On one of these horizons, viz., that overlying the lower Possil ironstone at Keppoch, north of Glasgow, *L. squamiformis* attained a size of one inch and a half in length, examples being figured by Dr. Davidson in his monograph as

* Carboniferous Brachiopoda, Supplement, p. 253.

the largest he had seen from British strata. On another, higher horizon, in the same group of strata to the north of Glasgow, on the sinking of a pit at Robroyston, to the upper Possil ironstone, there were found numerous examples of *L. squamiformis* and *L. mytiloides*, which were standing erect in the strata in the position they had lived and died in and with their valves united. So finely were their surfaces preserved that Dr. Davidson stated in a letter to the author, that they were the best preserved fossil *Lingula* he had ever seen. So abundant are *Lingula* in other portions of the Lanarkshire coal-field that the late Dr. Rankin, of Carluke, in his table of the strata in that district, designates two beds in the series as the *Lingula* limestone and the *Lingula* ironstone.

The shells of *Lingula*, and those of *Discina* next to be noticed, differ in their mineral composition from those of most of the other genera of Brachiopoda in being corneous, or having a horny or chitinous structure. This character serves to distinguish them from other shells, even when they occur as fragments. Specimens of *L. mytiloides* from Scotch strata, showing remains of colour markings, have been described by Mr. Robert Etheridge, jun., and by myself. This shell is also often found with a fine bluish tint in the East Kilbride beds.

Regarding the other two Carboniferous species found in our strata, *L. Scotica* and *L. Thomsoni*, I have only to remark that both are rare. *L. Scotica* is a large species and is remarkable for its triangular shape. It was first found by Dr. Rankin in the Gare limestone shales, Carluke, and by Dr. Slimon in two localities in Lesmahagow parish. I have also found it in the Boghead shales near Hamilton ; and more recently Dr. Davidson has figured one or two large and fine examples from Redesdale, in Northumberland.* *L. Thomsoni* is only as yet known from Carboniferous limestone strata, in Tirfergus Glen near Campbeltown, where it was discovered by Mr. James Thomson. I have very great doubts about this shell belonging to the genus *Lingula*. It shows no trace, in the examples that I have examined, of that peculiar horny appearance of the shell so characteristic of other species of the genus. Dr. Davidson, in his description, says nothing about the structure of the shell, beyond that it is "longitudinally and finely striated," and that he had only "seen two examples." One of my two specimens

* Carboniferous Brachiopoda, Supplement, pl. xxx.

shows the striæ on the surface, but they both show what is not seen in *Lingula*, viz., that the beak is slightly turned to one side, as is often found in Lamellibranch shells, so that its appearance is more like that of *Posidonomya* than *Lingula*. This being the case, and the apparent absence of the corneous shell, incline me to place a point of interrogation against the generic name in the list, until its shell-structure is further examined in other specimens.

Discina.—This genus is represented in Scottish Carboniferous strata by two species, only one, *D. nitida*, being common and found ranging from the marine beds of the Calciferous sandstone series up to those of the higher coal-measures in the Lanarkshire coal-field. It is also believed to be identical with one of the species found in the Permian strata of England, where it is known as *D. Koninckii*. It is rather a rare shell in most British localities, but in one or two horizons of the Scottish coal-field, in some of the limestone quarries, examples may be picked up by the hundred on the banks of weathered shale. One of these is the bed of shale separating Nos. 1 and 2 limestones of the Calderwood series, in the parishes of Blantyre and East Kilbride, where this species is found in excellent preservation and often of a larger size than elsewhere. The surface of the shell, like that of *Lingula*, as formerly stated, has a corneous or horny lustre, and is often met with of a bluish colour. Dr. Davidson has figured an example from these beds showing radiated, bluish colour-markings still remaining on the surface of the shell, and he has also been able to illustrate the interior of the valves from other specimens.

The other Scottish Carboniferous species, *Discina Craigii*, is rare. It was discovered by Mr. Robert Craig, of Langside, Beith, corresponding member of the Society, in the lower limestone series of the Dockra Quarry, Beith. Two examples were found, one of which is figured and described by Dr. Davidson as *D. Craigii*, Davidson.* It measures one inch eight lines in diameter and is the largest species of the genus that ever came under Dr. Davidson's examination. Subsequently another example of this shell, one inch and three-quarters in diameter, was obtained by Mr James Neilson from a cutting of the Union Railway, north-east of Glasgow, in a bed of sandstone containing marine shells, lying close on the horizon of the upper limestone with the millstone grit series of

*Carboniferous Brachiopoda. Supplement, pl. xxx., fig. 14.

that district.* This species is not known from any other locality in our strata.

Crania.—The shells of this genus are often seen to assume various shapes, according to the form of the surface to which the lower valves are attached, but on the whole they have varied little in external form from their first appearance in the fossiliferous strata down to the present time. In the Carboniferous rocks of Scotland the genus is represented by only one species, *C. quadrata*, which is seemingly restricted to the strata of the lower and upper limestone series. In Scotland, as well as in England and Ireland, it is rare on most horizons, but in the shale of the Calderwood limestone series it is specially abundant, as at Capelrig Old Quarry, East Kilbride, where it is found clustered upon shells and stems of crinoids in a very interesting way. I possess a stem of a crinoid two inches long and one half inch in diameter on which there are remaining no fewer than sixteen examples of the lower or attached valve. These are seen to be, in some instances, so close together that the edges of shells, where they impinge upon one another, have often interfered with their shape and regular growth. Very good examples of the interior of the valves are found in this horizon, and from those Dr. Davidson has been able to illustrate the muscular impressions. The shells of *Crania* differ from those of *Lingula* and *Discina* in being calcareous, and when well-preserved, the upper or free valve is found to be minutely perforated, as is the case in many other genera of Brachiopoda. In the lower valve I have found no trace of perforations, and was therefore led to examine the lower or attached valve of *C. anomala*, the only living British species. I found in it very few visible perforations compared with those to be seen in the free valve, although it has been supposed that both valves were perforated alike. Had the lower valve of *C. quadrata* been perforated to any extent I could hardly have failed to have observed the fact in some of the numerous specimens I have examined, especially as in those specimens the perforations of the upper valve are well seen.

Clistenterata.

Dielasma (*Terebratula*).—The researches made during recent years into the internal characters and other points of structure in that extensive group of the Brachiopoda which now forms the family

* *Transactions*, vol. v., p. 227.

of the Terebratulidæ have led to the formation of several sub-genera. The *Terebratula* of the Carboniferous and other palæozoic strata are now placed in the genus *Dielasma*, of King, from their possessing septal and dental plates within their shells. According to Dr. Waagen (whom Dr. Davidson quotes in regard to these new sub-genera of the Brachiopoda), the genus *Dielasma* appeared first in the Devonian and continued up through the Carboniferous and Permian formations into the lower Trias, where it seems to have become extinct, and to have been replaced by another type or sub-genus of *Terebratula*. In Scottish Carboniferous strata, *Dielasma* is represented by four species which were at one time considered by Dr. Davidson to be only varieties of one type, *D. sacculus*, Martin; but in his revised list they now rank as species. One of these, *D. hastata*, is found in strata of the Calciferous sandstone series in the East as well as in the West of Scotland, but it is in the strata of the lower and upper limestones that they have been found most frequently, although they are everywhere rather rare shells.

None of the Scottish examples ever seem to have attained a length of more than one inch, and this dwarfed condition is also characteristic of several of the other genera of the Clistenterata found in Scotland, when compared with the larger and similar forms from the Carboniferous strata of England and Ireland. In the limestones and shales of the Beith district, as well as in those from the Brockley district, there are found numerous examples of a small race of *Dielasma*, chiefly *D. sacculus*, few exceeding one-fourth of an inch in length, while many are less than a line in diameter. The perforations characteristic of the shell-structure are often well preserved, especially in examples found in shales, and this character enables the genus to be easily recognized, even in strata where the shells are frequently found in a crushed and fragmentary condition. Specimens showing the interior of the valves are sometimes found in these shales, but they are very rare.

Spirifera.—This genus, which forms the type of the family Spiriferidæ, has now been divided into several sub-families and sub-genera, some of which fall here to be noticed. Of ten species of *Spirifera* recorded from the Carboniferous strata of Scotland in Dr. Davidson's former lists, only five are now retained, one found at Gillfoot, Carluke, a single valve of *S. triangularis*, in the late Dr. Rankin's collection, being, however, very doubtful. This speci-

men appears to me to be only a portion of the extended hinge-area of a rather wide example of *S. trigonalis*, such as is found in the shale of the same locality. This last-mentioned species and its variety, *S. bisulcata*, are by far the most widely distributed members of the genus within the coal-fields of Scotland, ranging from the Calciferous sandstone series up into the strata of the lower and upper limestones. *S. trigonalis*, the type species, presents us with several interesting and well-marked varieties, to which I formerly called attention in a paper read to the Glasgow Natural History Society, * noticing their vertical range and distribution within our coal-fields. I have also, in a more recent paper "On the denticulated structure of the hinge-line of *S. trigonalis*," † described the interesting character which, in specimens derived from our limestone shales, I discovered in connection with the hinge-area of this species. This character is also figured and described from the same specimens by Dr. Davidson in his Monograph, ‡ and in those notices fuller information regarding them may be had.

Martinia (*Spirifera*).—The species forming this sub-genus are now characterized by having a minutely perforated shell-structure, whilst those of *Spirifera* proper are not known to be perforated. This perforated character, as pointed out by Dr. Davidson, was not known to Professor M'Coy, when, in 1844, he proposed the genus *Martinia* for some of the *Spirifera* now there placed, doing so on the mistaken supposition that their spiral appendages were small, although Dr. Davidson has since shown this is not the case. There are amongst Scottish specimens of the genus very few examples which now show any trace of those minute perforations, but this is believed to be due to alteration of the shell-structure from fossilization. Dr. Davidson states that according to Dr. Waagen the punctured epidermis seems to be more easily destroyed in the shell of the true *Martinia* than in those of the sub-genus *Martiniopsis*, in which it is much better preserved and therefore more frequently found. Since that period I have discovered perforations in *S. ovalis*, which is closely allied in form to the genus *Martinia*, and is now placed with it in the list of species. On communicating this fact to Dr. Davidson, he wrote, Jan. 26th, 1885: "I am glad that you have found perforations in the shell of

* *Proceedings*, vol. iii., p. 373, 1876.

† *Geol. Mag.*, decade iii., vol. i. 1884, p. 18.

‡ Vol. v., part iii. 1884, p. 373.

Spirifera, or rather now *Martinia ovalis*. It did not surprise me to learn that you had found them, and I think it is quite right to separate the perforate from the non-perforate species." The specimen showing these perforations is a finely-preserved though small example from the limestone shales of the Brockley district, and I hope this structure will yet be found in other specimens.

On many Scottish examples of *Martinia Urei* (formerly *Spirifera Urei*), besides the covering of minute spines on the surface of the shell, which was first illustrated by Dr. Davidson from Scottish specimens, there is to be seen a beautiful reticulated ornamentation confined to the inner surfaces of the valves and the surfaces of casts. I have also found this structure in other Scottish Carboniferous Brachiopoda, and as it might be mistaken by some to be a kind of perforation of the shell-structure, I may explain that it is due to the cropping out on the inner surfaces of the valves of the bundles of shell-fibre which compose the structure of the shell, and which, in their oblique or inclined passage through its thickness, produce the imbricated arrangement of the ends of the bundles spoken of. This structure has been examined by the late Dr. Carpenter and others in recent Brachiopods, and examples of it are illustrated by Dr. Davidson in his monograph. *

Reticularia (*Spirifera*).—In Dr. Davidson's lists this sub-genus is represented from British Carboniferous strata by only one species and two named varieties. The genus extends from the Devonian up into the Carboniferous limestone series, and in Scotland is found ranging from the Calciferous series into the lower and upper limestones, but it is not very abundant in any of its localities.

The genus *Reticularia* was first proposed for this species and its varieties by Professor M'Coy in 1844, from the reticulate markings seen on the surface of the shell, but the name was not then adopted by palæontologists. It has, however, been revived by Dr. Waagen, and is now accepted by Dr. Davidson, owing to the discovery on the shell-surface of new characters, only recently observed, and not known to M'Coy or Davidson. These new characters were first noticed in 1880, and are now figured and described by Dr. Davidson in his monograph,† and may here be shortly mentioned,

* Vol. i., parts v. and vi.

† Carboniferous Brachiopoda, Supplement, vol. iv., pl. xxxiv., fig. 9, p. 275.

as consisting of a series of barbed spines, arranged in concentric lines, upon the surface of both valves. These spines were hollow, and consisted of two tubes, as in a double-barrelled gun, which ended in two small pores on the surface of the shell. The bases of these spines have produced the reticulations on the surface from which the genus now takes its name. The hooklets on the spines are arranged in two parallel rows, and their points are directed towards the free ends of the spines, or away from the shell. This structure I first discovered in a specimen from the Blantyre shales, and I have since observed it in examples from other localities. The characters here noticed have not yet been observed in any other Brachiopod shell, recent or fossil. I have also found, in a specimen from the Brockley shales, that this genus is further characterized by having a minutely perforated shell-structure, as in *Martinia ovalis*.

Spiriferina.—This genus is represented by four species in the Carboniferous strata of Scotland. The most common species, *S. cristata*, variety *octoplicata*, is found in certain of the marine beds, ranging from the Calciferous series up into the lower and upper limestones. Another species, *S. Etheridgei*, Dr. Davidson found at Fullarton quarry, near Temple, Midlothian, in the lower limestone, and it has not yet been identified from any other locality in Britain. None of the species are common in any of the localities in which they are met with. They are readily recognized from species belonging to the true *Spirifera* by their strongly perforated shell-structure.

Athyris.—Four species belonging to this genus have been found in Scotland. One of these, *A. pisum*, Davidson, a small form got by Mr. James Thomson in the lower limestone shales at Brockley, has not yet been met with in any other locality. The most abundant species, *A. ambigua*, seems also to have had the greatest vertical range, being found in strata extending from the marine beds of the Calciferous series up into those of the lower and upper limestones. Several varieties of this species are found, and are well illustrated in Dr. Davidson's monograph. Another species, *A. Royssii*, is also moderately common in the lower limestone shales of the Beith and Brockley districts, where specimens may be picked up, showing the numerous concentric rows of flattened spines which completely covered the surface of the shell, and so characterize this species. The shells of the genus *Athyris* are not

known to be perforated in their structure, and may thus be known from shells belonging to the Terebratulidæ, but the fibrous bundles of their shell-structure sometimes form a reticulate ornamentation on the surface of casts, similar to that which I previously pointed out was seen on the casts of the shells of *Martinia Urei*, Fleming, and which might be mistaken for perforations.

Retzia.—This genus is the only other member of the Spiriferidæ yet found in Scottish Carboniferous strata, and is represented by only one species, *R. radialis*, which is found in both the lower and upper groups of limestones. It is a small shell, and is rare in all its localities, but may be known from shells of *Rhynchonella*, which it externally resembles in its form and ribbing, by having a minutely perforated shell-structure as in the Terebratulidæ.

Rhynchopora.—The shells of this genus externally resemble those of the Rhynchonellidæ, but are distinguished from them by having a perforated shell-structure. Only two species of the genus are yet known, one being from strata of the Permian formation in Russia, the other from the Carboniferous strata of the Beith and Dalry district in Ayrshire. At Bowertrapping there, where it was first discovered, it sometimes occurs in abundance in a gregarious condition in certain portions of the limestone, but is rare or absent in other parts of the bed. It has not yet been recorded from any other British limestone strata.

Camarophoria.—This forms another genus of the Rhynchonellidæ, and is represented in Scottish Carboniferous limestones by two species, both rare, and only recorded from the lower beds. Externally the shells strongly resemble *Rhynchonella*, and I have no doubt that specimens may exist in collections under that name. They may be distinguished from shells of that genus by their converging dental plates, and by one or two other internal characters, which are rarely visible on the surface of the shells, but may be exposed by etching them with acids.

Rhynchonella.—This genus, the type of the family Rhynchonellidæ, is represented in Scottish strata by three species, one of which, *R. pleurodon*, ranges from the marine beds of the Calciferous series up into those of the lower and upper limestones, but in the later deposits it became rarer, and generally of smaller size. *R. pugnus*, on the other hand, is more common in the later

deposits than in the earlier beds. The third species, *R. Brockleyensis*, Davidson, was found by Mr. James Thomson in the lower limestone shales of the Brockley district, where it is a rare shell, not having yet been recorded from any other locality in the strata of the Scottish coal-fields. I may here mention that the largest and finest examples of *R. pleurodon* I have yet seen from the strata of the West of Scotland are found in a bed of shale underlying the coralline limestone band at Corrieburn on the Campsie hills, but even there it is only about half the size of some of those from the English limestones.

Orthis.—This genus, forming one of the three members of the family Strophomenidæ found in Scottish Carboniferous strata, falls here to be noted. Though extremely abundant in species in the strata of the Silurian period, this genus is represented in British Carboniferous strata by only four species, one of which is doubtful. In Scotland two of the four species are found, one being *O. resupinata*, which ranges from the Calciferous series up into the lower and upper limestones, but is only moderately common in any of the localities. *O. Michelini*, the other species, is abundant in some of the strata of the lower limestones of the Beith district, where fine examples may be picked up showing the outer covering of spines, and the muscular impressions in the interior of the shell. The shell-structure of the genus is minutely perforated, that of *O. Michelini* showing perforations of various sizes. Dr. Davidson figures and describes * what he terms a small variety of *Orthis resupinata*, with widely separated beaks, from Corrieburn, Campsie. This form is, I think, more closely related to the one he has figured as *O. Keyserlingiana*, De Koninck, than to the former species, although placed provisionally with it, but is probably a distinct species from either.

Streptorhynchus.—This genus is represented in Scottish Carboniferous strata by one species and three named varieties. *S. crenistria*, the type form, is found ranging from the Calciferous series into the upper limestones, and is extremely abundant in certain districts, as at Auchenskeoch, Dalry, from which locality Dr. Davidson in his Carboniferous monograph has figured examples, which measured from five to six inches in width, by three and a half inches in depth, being the largest yet found in British strata. The varieties of this species found in Scotland are more

* Carboniferous Brachiopoda, pl. i., fig. 15.

rare, and more local in their distribution than the type form, some being confined to certain horizons of the upper limestone. In my examination of the shell-structure for Dr. Davidson, I found that the perforations were confined to the inner layers of the shell, and presented the same characters as those seen in shells of the family Productidæ.

Strophomena.—This genus appears to be represented by only one species and one named variety in the Carboniferous strata of Scotland. It is rather a rare shell, and has only been met with in strata of the lower and upper limestone groups. The perforations are confined to the inner layer of the shell, and are somewhat widely apart, lying in an inclined and slanting direction towards the beak. The most interesting and noticeable character observed in connection with Scottish examples of *Strophomena analoga* and its variety *Strophomena distorta*, and which Dr. Davidson was never able to explain, is the way in which the vascular impressions on the interior of the shell are seen to radiate in a continuous manner from the beak all over the inner surface, instead of forming a ring around the ovarian spaces, as had been already figured and described by Professor King and Dr. Davidson from examples found in the English Carboniferous limestone. Examples showing this peculiarity in the Scottish specimens were found in the Main limestone at Campsie and at Bowertrapping, near Dalry, one being figured by Dr. Davidson.*

Productus.—Of all the genera of Carboniferous Brachiopoda found in Scotland, none so abundantly represents the group as that forming the family Productidæ, Dr. Davidson identifying no less than twenty-five species, including one or two named varieties. From the whole of the Carboniferous strata of Britain some forty species have been obtained, but this list includes also one or two named varieties. From the abundance of certain species in the strata of the Scottish coal-fields, some of the beds are known as the *Productus* limestone and shales. The genus ranges from the lower beds of the Calciferous series into that of the lower and upper limestones, millstone grit, and upper coal-measures, becoming, so far as known, extinct in the strata of the Permian formation. Whilst many of the species of *Productus* are very abundant in all the strata in which they are met with, others are very rare, being confined to a few localities and to certain horizons.

* Carboniferous Brachiopoda, Supplement, pl. xxxvi., fig. 23.

The places where these have been chiefly found are noted in the "Catalogue of Western Scottish Fossils," Glasgow, 1876, and need not here be repeated. The most important characteristic noted by Dr. Davidson in connection with Scottish specimens of this genus is the light which they enabled him to throw upon the internal muscular impressions in the shells of many of the species, and also of the spines which were once adherent to their surfaces. These specimens were chiefly obtained from the shale beds and from the rotted limestones, and will be found illustrated in the Carboniferous monograph as well as in the later Supplement to it. While Dr. Davidson was engaged in his investigation of the group, I was also privileged to prepare for him examples of nearly all the Scottish species, to show the nature of the shell-perforations. Previous to this period very little was known of the shell-structure in *Productus*, and the work proved of greater interest than either of us anticipated when first taken up. We found that whilst the perforations in the shells of the Productidæ were all on a similar plan—confined to the inner layers of the shell and not passing to its external surface—yet they varied much in character in the several species. Some of these structures are illustrated by Dr. Davidson in the Carboniferous Supplement,* and the species examined are described in the text. I have only further to mention in connection with *Productus* that an esteemed member of this Society, Mr. James Bennie, of the Geological Survey of Scotland, discovered at Skaterow Harbour and East Barns Quarry, near Dunbar, in the lower limestone series, a species of the genus which was adherent by its spines and often by one of its valves to crinoid stems, shells, and fragments of polyzoa. This very interesting form has been illustrated, described and named *Productus complectens* by Mr. Robert Etheridge, jun.† I have also to note the finding of a specimen of *Productus scabriculus* with a broad-margined fringe or band of about three-eighths to five-eighths inch in width around the outer edge of the shell. This character has sometimes, but very rarely, been noticed in connection with other species of the genus. The specimen in question I found in the limestone at Hillhead Quarry, Beith, Ayrshire.

* Plate xxxvi.

† *Quarterly Journal of the Geological Society*, vol. xxxii., pls. xxiv-xxv. The description and figures are also reproduced in Dr. Davidson's Carboniferous Brachiopoda, Supplement, pl. xxxv.

Chonetes.—This genus is represented by four species in Scottish Carboniferous strata, and ranges from the Calciferous series into the lower and upper limestones. It is rare in the purer limestone beds, but in the alternating shales one or two of the species are abundantly met with in several localities in Scotland. The largest and most widely distributed species, *Chonetes Laguessiana*, is found in fine preservation in the shale which separates the Nos. 1 and 2 limestones of the Calderwood series, in the parishes of Blantyre and East Kilbride, Lanarkshire. From this horizon I have been able to examine the shell-structure of *Chonetes* in specimens of this species for Dr. Davidson, and it will be found figured and described in the Appendix to his Supplement.* Previous to this examination little or nothing was known of the true nature of the perforations in *Chonetes* nor of the passages of the tubular spines on the hinge area of the ventral valve as pores which open to the interior of the shell. I was therefore much pleased to be able to reveal these structures in Scottish specimens, and to find that they closely agreed with those I had previously found in the Productidæ.

Aulacorhynchus.—This genus, the last in Dr. Davidson's list of Carboniferous Brachiopoda found in Scotland, is represented by only one species, *A. Davidsoni*, and was obtained from the limestone at Clatteringwell Quarry, Bishops' Hill, Kinnesswood, Kinross-shire, the specimens now being in the Museum of Practical Geology, London. This shell at first was doubtfully identified by Dr. Davidson as belonging to *Chonetes concentrica*, De Koninck, and is figured and described by him as such in the Appendix to his Carboniferous monograph.† In the Appendix to Supplements,‡ Dr. Davidson again refers to this shell, and states that it also had been found, along with other species of *Aulacorhynchus*, in the Asturias, a province of Spain, and that the Scottish form had received the name of *A. Davidsoni*, Barrois. The genus is also found in American Carboniferous strata, but since Dr. Davidson described the shell no other examples seem to have been found in Scotland or elsewhere within the British Isles.

I have only further to remark before concluding these notes that there is not much likelihood of the list of genera and species

* Vol. v., pl. xx., pp. 280-283.

† Vol. ii., p. 278, pl. lv., fig. 13. ‡ Vol. v., p. 283.

of the Brachiopoda being much further increased from Scottish Carboniferous strata. Still, there is reason to hope that, as new localities are opened up, some of the Carboniferous forms found elsewhere in Britain may yet be found within the area of our coal-fields. There is, however, more important work still to be done amongst this class of organisms than the finding of new genera and species, and that is, in trying to discover amongst certain of the genera better preserved examples of the species showing the internal muscular impressions and other interior characters; likewise, in trying to discover in the more perfectly preserved examples of other species what were the external characters on the surface shell, as also the nature of the perforations, where such exist, in the shell-structure. Already Dr. Davidson has been able to throw much light on some of these points from the study of Scottish specimens, which often have their shell-structure better preserved than in examples obtained from the English and Irish limestones, in which the shells are found to be often much altered by crystallization or other metamorphic changes.

In preparing the following list of genera and species of the Carboniferous Brachiopoda found in Scotland, I have consulted for the Calciferous division of the strata the list given in Dr. Bryce's "Geology of Arran";* the papers of Mr. Robert Etheridge, jun., "On Lower Carboniferous Invertebrata";† and that of Mr. J. W. Kirkby "On the Zones of Marine Fossils in the Calciferous Sandstones of Fife."‡ For those of the lower and upper limestone strata, millstone grit, and upper coal-measures, I have consulted the lists in Dr. Davidson's monograph, "Catalogue of Western Scottish Fossils," "Explanations of Sheets 23 and 31 of the Geological Survey Map, Geological Survey Memoirs, 1873-1879," and the various papers in the *Transactions* of this Society which contain lists of Carboniferous Fossils.

* Fourth edition, 1872, p. 225.

† *Quarterly Journal of the Geological Society*, 1878, vol. xxxiv., p. 23.

‡ *Ib.*, 1880, vol. xxxvi., p. 588.

REVISED LIST OF

SCOTTISH CARBONIFEROUS BRACHIOPODA, 1885.

GENERA AND SPECIES.	Calciferous Sandstone Series.	Lower Carb. Limestone Series.	Upper Carb. Limestone Series.	Millstone Grit Series.	Coal Measures.
TRETENTERATA.—*King.*					
Lingula mytiloides, Low.	x	x	x	x	x
,, *squamiformis*, Phill.	x	x	x	x	x
,, *Scotica*, Dav.		x	x		
,, (?) *Thomsoni*, Dav.		x			
Discina nitida, Phill.	x	x	x	x	x
,, *Craigii*, Dav.		x	x		
Crania quadrata, M'Coy.		x	x		
CLISTENTERATA.—*King.*					
Dielasma (*Terebratula*) *hastata*, Sow.	x	x	x		
,, ,, *sacculus*, Mart.		x	x		
,, ,, *resicularis*, De Kon.		x	x		
,, ,, *Gillingensis*, Dav.		x			
Spirifera duplicicosta, Phill.	x	x			
,, *triangularis* (?), Mart.			x		
,, *trigonalis*, Mart.	x	x	x		
,, ,, var. *bisulcata*, Sow.	x	x	x		
,, *triradialis*, Phill.		x			
Martinia (*Spirifera*) *glabra*, Mart.		x	x		
,, ,, *ovalis*, Phill.	x	x			
,, ,, *Urei*, Flem.	x	x	x		
,, ,, *Carlukensis*, Dav.		x	x		
Reticularia (*Spirifera*) *lineata*, Mart.	x	x	x		
Spiriferina cristata var. *octoplicata*, Sow.	x	x	x		
,, *insculpta*, Phill.			x		
,, *laminosa*, M'Coy.	x	x			
,, *Etheridgei*, Dav.		x			
Athyris ambigua, Sow.	x	x	x		
,, *plano-sulcata*, Phill.		x			
,, *Royssii*, Leveillé.	x	x	x		
,, *pisum*, Dav.		x			
Retzia radialis, Phill.	x	x	x		
Rhynchopora Youngii, Dav.		x	x		

GENERA AND SPECIES.	Calciferous Sandstone Series.	Lower Carb. Limestone Series.	Upper Carb. Limestone Series.	Millstone Grit Series.	Coal Measures.
Camarophoria crumena, Mart.		x			
,, *globulina*, Phill.		x			
Rhynchonella pleurodon, Phill.	x	x	x		
,, *pugnus*, Mart.		x	x		
,, *Brockleyensis*, Dav.		x			
Orthis resupinata, Mart.	x	x	x	x	
,, *Michelini*, Leveillé.		x	x		
Streptorhynchus crenistria, Phill.	x	x	x	x	
,, ,, var. *radialis*, Phill.		x	x		
,, ,, var. *senilis*, Phill.			x		
,, ,, var. *cylindrica*, M'Coy.		x	x		
Strophomena rhomboidalis var. *analoga*, Phill.	x	x	x		
,, ,, var. *distorta*, Sow.			x		
Productus giganteus, Mart.	x	x	x		
,, *latissimus*, Sow.	x	x	x		
,, *cora*, D'Orb.	x	x	x		
,, *semireticulatus*, Mart.	x	x	x		
,, ,, var. *Martini*, Sow.	x	x	x		
,, ,, var. *concinnus*, Sow.	x	x			
,, ,, var. *Scoticus*, Sow.		x			
,, *costatus*, Sow.	x	x	x		
,, ,, var. *muricatus*, Phill.		x	x		
,, *scabriculus*, Mart.	x	x	x		x
,, *pustulosus* (?), Phill.		x			
,, *carbonarius*, De Kon.			x		
,, *longispinus*, Sow.	x	x	x		
,, *Griffithianus*, De Kon.		x			
,, *sinuatus*, De Kon.			x		
,, *fimbriatus*, Sow.		x			
,, *aculeatus*, Mart.	x	x	x		
,, *Youngianus*, Dav.	x	x	x		
,, *punctatus*, Mart.	x	x	x		
,, ,, var. *elegans*, M'Coy.		x	x		
,, *undatus*, Defr.		x	x		
,, *mesolobus*, Phill.		x			
,, *spinulosus*, Sow.		x			
,, *Deshayesianus* (?), De Kon.		x			
,, *complectens*, R. Ether., jun.		x			
Chonetes Laguessiana, De Kon.	x	x	x		
,, ,, var. *gibberula*, M'Coy.		x			
,, *Buchiana*, De Kon.		x	x		
,, *polita*, M'Coy.	x	x	x		
Aulacorhynchus Davidsoni, Barrois.		x			
Total number of species found in each series,	33	67	52	5	4

No. XII.—The Old Red Sandstone of Lanarkshire, with Notes on Volcanic Action during Old Red and Carboniferous Times.

By John R. S. Hunter, D.Sc., LL.D., F.R.Ph.S.E., etc., *Honorary Member.*

[Read 28th May, 1885.]

The Old Red Sandstones or Devonian formation, mainly composed of nearly pure sandstones and conglomerates, and lying above the Upper Silurians, is largely developed in Lanarkshire. The lower beds of conglomerate extend over a considerable portion of the parish of Lesmahagow. The matrix of this conglomerate is a coarse-grained sandstone of a dun or purple colour, with quartzite nodules of a slightly flattened oval shape of from half an inch to 15 inches in diameter, and pieces of red and bluish-grey jasper. These beds are quite different from the higher conglomerates of the Old Red, which are light brick red in colour.

The Old Red is best developed in the Hagshaw, Whitehaugh, Greenock, Avon, Glengaril, Kype Water, Lesmahagow, and Lanark districts, and the Tinto and Carmichael districts from Tinto Hill to the Clyde, also in the Kilncadzow or Carluke area to the N.-E. of the town of Lanark. All these are connected with each other.

A good idea of the structure of Lanarkshire may be got by supposing a ridge or axis of rock to run through the middle of the field in a sinuous, easterly and westerly direction. From the north side of this ridge, the limestones, coals, etc., dip northwards, forming the Clyde coal-field. On the south, a small area of the Ayrshire coal-field is seen round Glenbuck. The ridge itself consists chiefly of Lower Old Red, forming an expansion of the belt of that formation which stretches across the country from near Edinburgh into Ayrshire. On the west side, it is prolonged northwestward by the Lower Carboniferous volcanic rocks running from Stonehaven as a broad strip of elevated ground between the plains of Ayrshire and the valley of the Clyde. Owing to numerous foldings and fractures of the Old Red Sandstone, portions of the underlying Upper Silurian strata are brought to the surface, but the former wraps round them, and abuts against the great Lower Silurian uplands of the South of Scotland. The strata of the Old

Red attain a great development between the basin of the Clyde near Lanark and the Ayrshire coal-fields, reaching possibly a thickness of 12,000 to 15,000 feet. At Bonnington Falls, the rocks occur in layers of from an eighth of an inch to several feet in thickness, the former having clay nodules interspersed. From Bonnington to Cora Linn, the Clyde flows through a magnificent wild ravine of about half a mile in length, the waters of the Clyde being hemmed in by vertical jointed walls of Old Red strata, at Cora Linn the water descending a sheer fall of 84 feet, and a short way below the precipitous sides being about 150 feet high. The sandstone varies considerably in colour, sometimes resembling a hard ferruginous clay, while a large portion is thickly studded with plates of mica.

The lithological features at Stonebyres Falls are similar to those at Cora Linn, except that here and there we find a great cliff of conglomerate protruding into the stream from beneath the Old Red Sandstone. Thin seams of conglomerate are also interlaminated with the prevailing rock at various heights. The contained fragments are both rounded and angular, consisting of quartz, felstone, porphyry, claystone, greenstone, and jasper.

At Tinto the Old Red formation contains intercalated masses of trappean agglomerates, which, with interbedded felspathic rocks, extend north-eastwards towards the source of the Nith. In the valley of the Irvine Water at Lanfine, Ayrshire, it consists of a grey micaceous flagstone with trappean agglomerates and felspathic traps. Here it has yielded a few specimens of *Cephalaspis Lyellii*, being the only locality in the South of Scotland where remains of this fish have been found till very recently (1884). I have now the pleasure of showing you a magnificent specimen from the Lower Old Red of Lesmahagow, the portion represented being that of the buckler or shield-plate of the head. The position of the eyes is plainly visible, and from them two ridges extend backwards to the end of the shield-plate, but do not show any portion of the horn-like processes, which have probably been broken away. The most interesting point in connection with the specimen is the occurrence over the whole surface of the buckler-plate of a strongly marked system of vascular canals, which branch outwards in all directions from central stems, and which, as they reach the outward extremity bordering the rim, become very much branched. Where a portion of the buckler-plate has been lifted off on the

left hand side, the inner surface shows a peculiar strongly lobed appearance. The vascular ornamentation of the Lesmahagow specimen is more apparent than that of either English or Forfarshire ones. On comparing the canals on my specimen with those seen on a portion of the shield of *Zenaspis Salweyi*, I find the former to be much larger than those figured, (and magnified 4 diam.) in the valuable monograph on the fishes of the Old Red Sandstone by Mr. James Powrie, F.G.S., Reswallie, near Forfar.*

Before the Lesmahagow specimen was sent to Mr. Powrie, my kind friend, Mr. John Young, F.G.S., of the Hunterian Museum, Glasgow, carefully examined it, and as we came to the conclusion that it probably was a new species, I have ventured to name it provisionally *Cephalaspis Glottensis*, but I hope that before long other examples may be found in the same horizon, so that the doubtful points may be fully cleared up.

Organic remains of marine origin were found by the officers of the Geological Survey at Carmichael Burn in a thin shale about 5,000 feet above the base of the Old Red; but the formation, so far as yet observed in Lanarkshire, is very unfossiliferous, indicating a condition of things in which the waters were not conducive to organic life, probably from the excess of iron sediments in them. Peroxide of iron is also unfavourable to the preservation of organic remains, and may, in many cases, account for their disappearance. Lately, when examining a few cut corals which had been imperfectly cleansed from this substance, which is used for polishing them, I found that the smooth surfaces had, in the course of a few hours, been largely bitten into.

* Mr. Powrie, after comparing this specimen, wrote me as follows:—"From a large portion of the head being broken off, and thus its form when entire being lost, and also no portion of the outer surface of the cephalic plate being preserved, it is impossible to say with anything like certainty to what species it may have belonged, but on the whole I think it more probably belongs to *Cephalaspis Lyellii* than to any other with which I am acquainted. It is the impression of the inner surface containing the vascular canals, and these are better preserved in your specimen than in any one of the many others I have examined. Indeed, from the preservation of these canals, and their so distinctly marked character distinguishing it from those with which I am acquainted, I think it just equally probable that its species may be distinct from any of our Forfarshire Cephalaspids." Since the publication of the valuable monograph by the Palæontographical Society, very little has been added to our knowledge of this interesting genus.

The extremely red colour of the strata seems to indicate some peculiarity in the original medium of deposition by which it may have been communicated to the deposited sediments. What reason can be assigned for the various coloured sandstones we frequently meet with—red, white, yellow, and many different shades? Is it owing to the greater quantity of iron or other metallic oxides, or to some influence of electrical agencies by which rocks of all ages have been more or less affected?

A small space often separates, both horizontally and vertically, the white from the red-coloured sandstone, which favours the supposition that the elements of colour have been induced subsequent to the deposition of the rock. White circular spots are very common in this rock. In these it is evident that either the colour has never been present or has been afterwards expelled. It has often been supposed that such spots are due to the presence of organic matter, but as no traces of that have been found in them it is more reasonable to suppose that they are due to chemical causes.

One of the most remarkable features of the Old Red Sandstone in the West of Scotland is the occurrence of numerous basic trap dykes, probably of Tertiary age, with a general direction of west to east. The same dykes also traverse the coal strata of Ayrshire. Two areas of older volcanic action seem to have existed, one in the north-east, with its centre in the Pentland Hills area, where the porphyrites are thickest, the other in the south-west of Lanarkshire, while between them lay a space originally occupied by small islets of Upper Silurian rocks, over which the thick grits and conglomerates make their appearance. During the same geological period volcanic action was frequent along the whole of the midland valley of Scotland, since to that time we must refer the origin of the Ochil and Sidlaw Hills, part of eastern Berwickshire, and the long line of uplands from the Pentland Hills through Lanarkshire, across Nithsdale, and far into Ayrshire. Early in the Carboniferous period, and from then onwards through nearly the whole of the time occupied by the deposition of the Calciferous and Carboniferous limestone series, the district to the west of Edinburgh was dotted over with small cones, which were usually of tuff, but sometimes of different basic dolerites, more especially in the space between Bathgate and the Forth, where a long bank, chiefly formed of such lava flows, was piled up over and amongst the pools and shallows in which the

limestones, sandstones, shales, and coals, were afterwards accumulated. Northwards, also, similar volcanic activity was shown in the Fife coal-tracts near the Forth, while eastwards between Haddington and Dunbar there lay a distinct volcanic centre or focus, from which great sheets of porphyrite were ejected so as to form a bank over which and around the Carboniferous limestone series was at length deposited.

An interesting feature is the series of doleritic dykes which show a marked uniformity of direction, generally westerly and easterly, and which, when they traverse tracts of trappean rocks, continue as readily separable from them as when they intersect sandstones or shales. These dykes run across a great part of Scotland and into the North of England.

Faults and dykes, as may be seen from the geological maps of the district under review, are numerous, both in the Old Red Sandstone and in the Carboniferous rocks. Dykes are fissures filled with foreign matter, generally of igneous origin, which cut the strata in a perpendicular or inclined position, and are frequently of great vertical extent, the strata having been in some instances tilted up, or in others depressed on one side or other of the dyke. They sometimes lie obliquely to flows in the plane of stratification. Faults have evidently been produced by earth movements and pressure from beneath, occasioned probably by the same subterranean forces which ejected the matter of the dykes, and of those interstratified and intrusive beds of igneous rock of such common occurrence in our coal-fields.

Intrusive sheets of diabasic rock or dolerite are frequently observed in some parts of the Old Red, but in other places they seem interbedded. A fine example of the former may be found in the great intrusive sheet which extends from the East Neuk of Fife westwards through the Lomond and Cleish Hills, appearing again in the Abbey Craig at Stirling, and continuing on to Kilsyth, but always near the horizon of the Main or Hurlet limestone. The changes produced on the surrounding strata by the trap have been in many places excessive, their structural characters being altogether altered. Coals and limestones are rendered valueless, while shales and sandstones are greatly indurated at the points of contact. Sandstones, shales, and limestones are often greatly jointed and fissured, and sometimes assume the external form of basalt, while the dolerite has become calcareous and felspathic.

In the Wishaw coal-field, Glasgow Iron Co.'s No. 2 pit, there is a body of trap of a whitish colour, thirty feet from the bottom of the splint coal, about two feet thick and perpendicular in position, running due north and south, and probably being an altered dyke of dolerite. In Newmains district numerous dykes are observed, some being greenish and others whitish, which is due to various stages of alteration of the dolerite. In the parish of Carluke trap rocks, chiefly dolerites of various kinds, are seen at Hillhead, Barnhead, and Westerhouse. From Hillhead they run eastwards by Thorn and Bashaw. At Westerhouse they are merely seen projecting from a small elevation, and in Guildshields Burn they are seen passing towards Burnhouse. At Hillhead, where they are seen in beds 20 feet thick, and were at one time extensively worked for road metal, the columnar form is finely shown. The top and bottom is close grained and brittle, while the centre is highly crystalline. The wider fissures between the columns are filled with clay and boulders, while the smaller ones contain various crystals. The trap overlies clay shale, blackened in colour and otherwise altered. The dolerite terminates partly on the blue shale above the Hosie limestone, which is burnt of a brick colour. In some parts of its course it lies between the Hosie and the Main Post limestones. At Hillhead the Hosie limestone passes round the west point of it at a high angle, almost on edge, dipping on the north side to the north-west. At the west point of the dolerite the dip is west, on the south, south-west. At the extreme west point the ironstones are thrown back upon themselves, and the shale and its ironstone balls have a peculiar colour, while the limestone which lies on the dolerite is a soft mass of ochre. At Guildshields a volcanic rock is cut through by the stream. Near Kilncadzow several remarkable necks were exposed in the opencast ironstone workings. They cut the strata vertically and were circular in shape, being somewhat wider at the top of the quarry than at the bottom. They were filled with angular debris or agglomerate of Carboniferous rocks dipping towards the centre of the neck, where also the largest blocks of sandstone, shale, limestone, ironstone, etc., occurred. None of the fragments were igneous rock, but a few string-like veins of white dolerite penetrated the mass here and there. The white dolerite was seen at No. 2 pit, Old Hill, when sinking to the Raesgill ironstone, and was again observed at Langshaw when an air shaft was being put down to the main limestone workings.

Again, in No. 3 Main Limestone pit at Braidwood Station the same character of trap was again seen, but the bed was horizontal and formed the roof of the main coal formerly wrought by the author's firm. The limestone here was in a very confused condition, showing that probably other dislocations were near at hand.

Craigenhill doleritic rock, which is of a black colour, was frequently got below the main limestone, running from two feet upwards in thickness. At Coldstream in the Old Red Sandstone a reddish felstone is seen, and with a thickness of 30 feet is extensively worked for road metal. At No. 2 Orchard Gas Coal pit, near Crossford, a vein of dolerite runs from north-east to south-west. It penetrates up the shaft, so far as is seen, 27 fathoms, and its width is between two and three feet. In the dross coal above the gas coal the burning by the trap extends about three feet, while the gas coal is only altered for about one foot. The sandstone has also become very like kinglestone, and the fireclay is black and vitrified.

In the parish of Lesmahagow many of the hills are of igneous felspathic rock, intermixed with Old Red Sandstone, the most conspicuous being Todlaw in the upper and Blackhill in the lower end of the parish. Both of these hills consist of great outbursts of felstone porphyry, but, while the first is dark in colour the other is light. The Clarkstone, Dillar, and Boreland Hills, and Differick, which are composed of Old Red Sandstone, all lie in the lower end of the parish and slope towards the Clyde, whilst the Lowries, Gregstone, Wardlaw, Whiteside, Auchrobert, Skillyhill, and Chapel Hills, situated in the upper division, show eruptive action. At Cumberhead and Pockmuir Burn the white concretionary or nodular limestone appears, and, like the other rocks, in a vertical position. The Old Red rocks extend to the south and form Blackend Hill. In the burn beyond Craigenrigg, they again appear in conjunction with the concretionary limestone, expanding towards the south and forming the great masses of the Hagshaw Hills, which are only interrupted by hornblende, porphyry dykes, and small patches of Silurian rocks. At the other side of the parish they cross Kype Water and form Kyperigg and the surrounding moorland districts, with a few patches of igneous rocks. From the Kerse onwards by Auchenheath Cottage and Craignethan Castle to the Clyde at Evonford, rocks belonging to the Carboniferous formation are exposed, but have been greatly broken up by dislocations. Near Lochanbank Mill on the Nethan the strata have been upheaved to

the north at least 80 fathoms, so that instead of finding corresponding beds upon opposite sides of the dislocation, we must look for them on the north side about 450 feet higher up in the section. The upheaving force has evidently come from the east, probably proceeding from the felstone porphyritic beds found in the Old Red Sandstone on the Clyde near the village of Hazlebank.

Another great dislocation is found between Cora Mill and Craignethan Castle, and here the strata are upheaved to the north more than 100 fathoms, the disturbing element, which has here come from the east, raising up the rocks underlying the farms of Blair, Craignethan, etc., whilst upon the Auchenheath side the outcrop only has been affected, the coal beds at their outcrop on Hallhill Burn being nearly on edge, as if the result of pressure from Stonebyres Hill.

Numerous dykes or dislocations have recently been observed during the working of the Auchenheath gas coal, some being of great magnitude, and others very small. One of the smaller ones commences at a thickness of about four or five inches, and running to the north-west gradually increases to six feet and upwards.

Slickensides are often seen in perfection near these alterations of strata, showing fine groovings and markings, whilst in other places some of the strata are polished like a mirror. The fireclays are ribbed, and some of the shale is cut through as cleanly as if by a knife, with the faces as bright as glass.

Near Auchenheath the intrusive dolerite rock is from three to nine feet thick above the gas coal, which it often penetrates. It is seen at Langlee above the coal, while in No. 15 pit it is beneath it. In this last pit it extends up the shaft as far as the position of the second Carluke coal, and is again seen at Craignethan Crags.

The ironstone below the gas coal at No. 15 pit is in one locality completely charred, while the coal is rendered useless. The colour of the dolerite here is light grey, which changes to nearly white when near the coal, with here and there black patches. From these facts it is evident that volcanic action has been not only very frequent amongst the Lanarkshire rocks, but has extended over very different periods of time.

No. XIII.—Notes on the Discovery of a Fossil Scorpion (*Palæophonus Caledonicus*) in the Silurian Strata of Logan Water.

By John R. S. Hunter, D.Sc., LL.D., F.R.Ph.S.E., etc., *Honorary Member.*

[Read 28th May, 1885.]

[Summary.]

In two previous papers read to the Society * I referred to the results of former expeditions to the Logan Water district in the Lesmahagow hills, and I then described the geological features of this group of fossiliferous Silurian strata, known to all who are interested in Scottish palæontology.

In June, 1883, I started on another expedition to Logan Water, under canvas, and for the first few days experienced weather wet and stormy enough to try the patience of the oldest campaigner. Nor were the rocks more favourable to us than the elements, and our earliest explorations were absolutely barren of results. But patience and perseverance conquer many difficulties, so after a visit home to procure dry clothing, we set to work with renewed vigour to open up a new horizon. Here a splendid specimen of an organism which appeared to be entirely new to me was turned out. Its curious comb-like structure suggested strongly to my mind the fact that it bore a great and general resemblance to a recent Scorpion. Soon after plant remains were discovered on the same horizon, and the probability became all the stronger that here we had disentombed a land-inhabiting and air-breathing animal from a lower position in the earth's crust than any previously known to us. If this supposition proved correct, here was a find surpassing any of my former discoveries in the Logan Water Silurians, and rendering the hardships we had undergone as nothing in comparison.

Later in the year, when I had leisure to examine the specimens collected during this expedition to Logan Water, I showed the organism above mentioned to several of the members of the Geological Society of Glasgow, amongst others to Messrs. John Young, F.G.S., and David Forsyth, M.A. After careful examination both of these gentlemen corroborated my first impressions as to the stranger being a true Scorpion. Though in a manner

* *Transactions*, vol. vii., p. 56, and p. 272.

recognizing the importance of the discovery, I took no further steps to have the fact recorded until the 18th of December, 1884, when after reading, before the Edinburgh Geological Society, a paper sent me by Prof. Gustave Lindström of Stockholm, entitled "Preliminary Notice on a Silurian Scorpion—*Palæophonus nuncius*, Thorell and Lindström—from the Isle of Gothland," I then exhibited the Logan Water specimen and read notes on its occurrence. Writing afterwards to Dr. Lindström, I mentioned the facts of the case, and he was generous enough to waive his right to priority of discovery.

This example of *Palæophonus Caledonicus* is as nearly perfect as any fossil organism in such old rocks is almost ever found. It is, however, fractured across, but this is rather an advantage, as it allows us to get a glimpse of structure which would have been otherwise hidden. A portion of the tail is turned sideways. The whole of the animal is unusually well preserved as compared with other Scottish Carboniferous specimens, which besides being squeezed flat, have some of the more perishable organs decomposed. Dr. John Young, Professor of Natural History in the University of Glasgow, has kindly consented to figure and describe this specimen, and I therefore hope to bring before you the result of his observations on a future occasion.

The vertical range of fossil Scorpions in Scotland may now be stated to extend upwards from the Upper Silurian to the Carboniferous formation. Their remains are frequently found in the Calciferous sandstones of the South of Scotland, where they are represented by the genus *Eoscorpius*. During Carboniferous times these air-breathers seem to have lived in abundance, as the strata of Fife and the Lothians are found to contain numerous fragments of their bodies. In the former county they have been traced by Mr. W. Tait Kinnear, an ardent worker of the Edinburgh Geological Society, extending from the Calciferous sandstones of Burntisland to the highest strata of the coal measures in the Leven and Largo districts, besides in other localities.

Is it not somewhat strange that so few remains of Scorpions have been found in the West of Scotland? a single fragment from the Carboniferous rocks only having been found in the Carluke area. It is high time that the West country geologists made a thorough search for traces of those interesting creatures, as no reasonable doubts exist that they will be found if carefully looked for.

No. XIV.—Notice of the late Mr. Andrew Patton, East Kilbride, *Corresponding Member*. By James Coutts.*

[Read 15th October, 1885.]

It will not, I am sure, be thought out of place that I should take upon myself the melancholy duty to-night of bringing before the Society as a body, what many of the members individually are already aware of, that our esteemed friend and Corresponding Member, Mr. Andrew Patton, of East Kilbride, departed this life on the 23rd of July last.

Many of the interesting and in some cases unique specimens of fossils from Mr. Patton's collection have been so frequently brought before the Society's meetings of late years that his name has become almost a household word amongst us, and I am certain that there is no one of us who will not regret his comparatively sudden and unexpected death.

Our friend was born of humble parentage in the county of Northumberland, near famous Flodden Field, in the year 1821; and, as might have been expected, he was sent at an early age to work in the colliery where his father was employed. His chances of schooling were thus very limited; but he soon began a system of self-culture which grew with his growth, and continued literally to the end of his life.

Entering into the bonds of matrimony as a young man, Mr. Patton came to Scotland, and obtained work at several collieries in Ayrshire and Renfrewshire, settling down eventually about the year 1858 as manager of the Calderwood Cement Works, in East Kilbride, and this situation he held for nearly a quarter of a century, until, indeed, the failure of Messrs. John Brown & Co., the lessees of the workings, which were then closed.

Having not only a practical but a theoretical experience of mining operations, Mr. Patton was soon found by both masters and men to be a thoroughly reliable and competent manager, while his calmness and self-possession in times of emergency or danger were of infinite service in keeping the works free from accidents. Indeed, his reputation extended so widely that he received various

* The author of this paper was himself removed by death a few months later. For a short notice of Mr. Coutts see *postea*, page 177.

tempting offers from coal and iron masters to change employment, but his affection for East Kilbride, where his early married life had been spent, and in the churchyard of which more than one of his children had been laid to rest, prevented him from accepting any of them, however advantageous they seemed to be from a worldly point of view.

Many years ago Mr. Patton began to interest himself in the fossil remains found in the strata amongst which much of his time was passed, and he soon became an ardent and skilful collector. By degrees the richness of his collection became known to palæontologists, and frequent visitors began to find their way to East Kilbride. To these he was only too liberal in the bestowal of specimens, and few left his house without some tangible memento of their visit. Specimens of the rarer and undescribed forms were coveted by the authorities of the public museums, and were on different occasions acquired by the Museum of Science and Art in Edinburgh, by the British Museum, and by others.* From first to last, the number of species added to the lists by Mr. Patton's instrumentality must have been considerable, while some of his discoveries still remain undescribed. One of the most notable of his finds was the fine specimen of *Psephodus magnus*, Ag., which has been lately figured and described by Dr. R. H. Traquair, of the Edinburgh Science and Art Museum, in the last part of our *Transactions*. (See vol. vii., pt. 2, page 392.)

In 1876, Mr. Patton sent to Glasgow for exhibition at the Corporation Galleries during the Meeting of the British Association a small but extremely interesting case of fossils from the cement limestones, and which attracted a considerable amount of attention. It was afterwards sent on loan to the Greenock Museum, where it remained till a quite recent date.

In 1880, he was, as a mark of respect, elected a Corresponding Member of this Society, an honour upon which he placed high value, and in the session of 1883-84 he contributed an interesting paper upon the Geology of his district, accompanied by sections drawn to scale, which showed his ability as a self-taught artist. To this paper I had the pleasure of appending a list of the fossils found in the East Kilbride district, the details being, of

* It may interest members to know that Mr. Patton's collection of East Kilbride fossils has lately been acquired by our Honorary Member, Dr. Hunter, for the "Braidwood collection," which he is now forming.—Ed.

course, to a considerable extent supplied by Mr. Patton himself. (See vol. vii., pt. 2, page 309.) The *Phyllopoda* in the list appended to Mr. Patton's paper were described by Mr. Etheridge, jun., and Mr. Woodward, in the *Geological Magazine* for 1872-73; *Palæsquilla Pattoni*, by Mr. Peach; and *Fissodus Pattoni*, by Mr. Etheridge, jun.

In addition to his ordinary work and his scientific pursuits, Mr. Patton took a great interest in matters relating to the social well-being of the district, the great success of the local Co-operative Society being due largely to the assistance he afforded it in its early days. He was above all of a most kind-hearted and simple-minded disposition, but so retiring and unobtrusive in all his actions that of him it might truly have been said in the words of Goldsmith, "He did good by stealth, and blushed to find it fame."

In conclusion, I may be permitted to state that though my acquaintance with Mr. Patton only began in the year following the Glasgow Meeting of the British Association, it quickly ripened into friendship, and consequently I formed the medium through whom so many of his rarer specimens were brought under the notice of the members. Mr. Patton has left to mourn his loss a wife and family, and I would, in conclusion, suggest that a motion of condolence with them in their loss be passed to-night, and an extract from the minutes be sent by the Secretary to Mrs. Patton.

No. XV.—The Geology of the Territory of Idaho, U.S., and the Silver Lode of Atlanta. By James Thomson, F.G.S.

[Read 11th December, 1884.]

[Summary.]

The Territory of Idaho is situated on the north-west extremity of the United States of America. It is bounded on the south by Utah, on the west by Oregon, on the north-west by Washington, on the north by British Columbia, on the east by Montana, and on the south-east by Wyoming. Its geological phenomena are varied and interesting. Immediately after crossing the boundary between Idaho and Utah there is an extensive sheet of vesicular lava, which extends for 340 miles across the territory in rolling undulations

which resemble Atlantic waves. The long axes of these ridges trend from south to north, and are here and there broken by circular depressions which prove on examination to be the mouths of extinct volcanic craters. Around their margins the lava is covered by a thin vitrified crust with minute undulations, like the ripple marks on a sandy shore, which are deflected in every direction, indicating that the flow of lava had been in some way obstructed.

The Snake River, resembling with all its turnings and windings the coils of an enormous serpent, has cut a deep channel, and its escarpments present an unbroken face of vesicular lava. Near the surface the vesicles are minute—in this respect like recent pumice-stone—but become larger and more irregular as we descend in the sections. Near the middle of this dreary waste, turning to the east at Mountain Home, the rough pathway lies across the surface of the lava for fully 30 miles. About midway the party crossed a series of mountains, trending south by west, the volcanic rocks being vesicular and rudely columnar, the columns variable, and usually from ten to twelve feet in diameter. Further to the east a descent was made into a plain, which seemed to be a vast extinct crater, with numerous miniature craters scattered throughout the main depression. On the northern margin the igneous rocks become more and more compact, merging into felspathic porphyry, which ultimately as dykes is seen piercing the granitic ranges of the neighbouring portion of the Rocky Mountains.

At the junction the party descended for about 3,000 feet into Lime Creek Valley, through which the South Bosie River flows, the pathway being along its banks. In the bed of the river were found boulders, representing the petrological history of the surrounding country—porphyries varying from compact cream-coloured varieties to deep greyish-blue ones, and running into vesicular dolerite, besides the different kinds of granite of which the mountains of the district are composed. On emerging from this valley one of the deep "gulches" or ravines which intersect the mountains in every direction was entered. On either side the slopes are all but precipitous, rising from 3,000 to 5,000 feet overhead, and covered with gigantic pines of from 200 to 300 feet in height, which grow up to 9,000 feet above sea-level. The rocks are granitic, and are traversed in all directions by quartz veins, cut and pierced in places by the porphyry formerly spoken of. The path for about 15 miles ran over mountains and through forests

and deep "gulches" of the most varied character. At one part we were in the depths of the forest, while at the next opening we looked down into a "gulch" several thousand feet deep, while beyond the intervening depression we saw the perpetually snow-clad peaks rising from 10,000 to 12,000 feet above sea-level.

Such is the track until Rocky Bar, our destination for the night, was reached. In this part of the world there is no twilight—the sun sets, and we were all but instantly enshrouded in the deepest darkness. Having travelled so far across the lava plains, over the mountains, down into and along the margins of numerous "gulches," and through deep forests, there was no reluctance to end the day's work.

In the grey dawn of the next morning, at half-past five o'clock, the party were again on the road, taking first through the "city," which consists of a few scattered and irregularly built wooden shanties, placed on both sides of a deep "gulch," which is bounded by mountains 3,000 to 4,000 feet high. After an eight-mile journey through country similar to that previously crossed, the path began to ascend the Hogsback Mountain, which is clothed with tall pines up to the 9,000 feet level, and on reaching the summit the scenic aspect was found to be fine beyond description. On the north are first seen the Sawtooth Mountains; on the east we look up to Prospect Peak, from 10,000 to 11,000 feet high; on the west is a "gulch" about 4,000 feet below, with various lateral "gulches." Beyond the nearer mountains are seen the peaks of the snow-clad Blue Mountains. If all this outlook is varied in its physical aspect, no less so is its accompanying vegetation, from the great pines on the mountain slopes to the trembling aspens clothed in their rich autumnal tints, ranging from deep bluish-green to numerous shades of pale green, yellow, and even deep gold colour, whilst amongst other members of the vegetable world there are many other varieties of tint, from pale brown to blood-red. Above, below, near and far, all is clothed in nature's own wild and beautiful colouring.

Once more we proceed down the edge of a "gulch," near the bottom, the way in the distance seeming to be closed by a barrier extending across it, and ascending far up the sides. It is a gigantic dyke of felspathic porphyry, serrated and pinnacled along the top. The descent is steep until we reach the dyke, when we turn sharply round, and on looking up from the other side we

realize its magnitude and appreciate its great height. It pierces the mountain side, and is exposed to view for fully 1,000 feet upwards. The banks of the Middle Bosie River are now reached, and here, as in many of the "gulches" already passed, Chinamen were industriously at work at what is termed "placer" gold digging, which is simply washing the sandy and gravelly detritus brought down from the higher levels by natural causes. These Chinamen earn, it is said, from two to twenty dollars a day, even in spots that have already been washed by men of other nationalities. An examination of the wash-dirt led to the conclusion that the whole region here is more or less impregnated with gold.

The party at last reached its destination—Atlanta city—situated on the west side of Atlanta Mountain, and on the east side of the Middle Bosie River. It is surrounded by the Sawtooth range of mountains, the name of which was suggested by the presence of numerous bosses and dykes of felspathic porphyry ejected through the grey granite, of which these mountains are composed. The later igneous rock, where it came into contact with the granite, has altered it and rendered it more or less friable, and becoming disintegrated by weather and other abrading influences, it has been afterwards washed down to the valleys by melting snow and by rain, leaving the igneous rocks projecting in pinnacled masses, serrated on their upper edges.

Atlanta Mountain stands isolated from all other eminences, and reaches a height of fully 1,600 feet above the surface of the central depression from which it rises, its altitude above sea-level being from 7,000 to 8,000 feet. It occupies an area of about four square miles, the Middle Bosie River which flows on its north and the Yuba River on its south side forming a junction at its western extremity. It is formed, like the surrounding mountains, of a grey granite, containing large crystals of felspar. Along the summit there is a large fissure, extending from the eastern to the western side, which has been produced by the local disturbance caused by the eruption of the igneous rocks formerly referred to. This fissure was originally fully 50 feet broad, and has subsequently been more or less filled up with decomposed granite and quartz, containing a variable percentage of both gold and silver, and termed in the district "low grade ore." This is pierced in various directions by lodes of silver ore, more or less intermixed with gold. Along the lateral margins of the central lode of high grade ore

there are numerous lateral fissures of various dimensions, which also contain the precious metals. The fissures near the eastern extremity converge inwards in a slanting direction towards the central area of the great central fissure vein ; while those on the western side also converge inwards to the centre from the opposite direction, indicating that the centre of the main fissure is the focus or principal body of the precious ore. The great main fissure extends from the Buffalo Mine on the east to the west for 8,000 feet, and gold and silver are present throughout the entire distance. In a tunnel cut on the bank of the Yuba River to the south of Atlanta Mountain, the precious ores were found at a depth of 1,600 feet beneath the surface.

It will thus be seen that here there is a continuous lode rich in the precious metals 8,000 feet in length and 1,600 feet in depth, and where proved by the Yuba tunnel 70 feet broad. If the lode is as broad throughout its entire length, an important problem is suggested as to how such a fissure became charged with the precious metals.

No. XVI.—A Short Notice of the Late Mr. James Coutts. By John Young, F.G.S., *V.P.*

[Read 15th April, 1886.]

I am sorry to have again to bring before the Society this session another loss it has sustained by the death of our respected friend Mr. Coutts, which took place on the 19th March last, in the 76th year of his age. He was a member of the Society for the last eleven years, but was long previously known to many of us who were also members of the Natural History Society, of which he had been a member for nearly 20 years. Although his studies in natural science were taken up only after he had considerably passed the prime of life, yet he showed an enthusiasm in pursuit of them that was worthy of a younger frame. During all his membership he was a most regular attender of the meetings and excursions, and his familiar form will on these occasions be missed by all his friends.

Mr. Coutts attended my Class of Geology in the Mechanics' Institution for nearly ten sessions, and at the age of 66 or 67 he presented himself at the Government Science and Art Examina-

tions, gaining from the Department a 2nd class certificate for geology, an honour which he was deservedly proud of.

He wrote several short papers on geological subjects, which were printed in our *Transactions*, or in the *Proceedings* of the Natural History Society, and was a constant exhibitor at our meetings of a great variety of specimens, invariably accompanied by a note of remarks which he had worked up in the most painstaking manner. During the last few years, as will be remembered, he, meeting after meeting, brought under the notice of members many of the choicer and rarer fossils from the collection of his friend, Mr. Andrew Patton, of East Kilbride, and only last year he spent a great amount of time and trouble in the preparation for the *Transactions* of a list of Carboniferous fossils found in East Kilbride, which was appended to Mr. Patton's paper on the Geology of that district. [See vol. vii., pt. 2, p. 324.]

Mr. Coutts' last appearance before the Society was at the opening meeting of this session, when he read a short notice of the life and work of his recently deceased friend and our esteemed corresponding member. [See page 171.]

Although it had been noticed by his friends that during the past year Mr. Coutts' health and strength had considerably failed, yet as he stood here that evening testifying to the worth of his departed friend, there was no one amongst us whose mind was crossed by the thought that Mr. Coutts himself was so shortly to be called away, and before the close of the same session. It is pleasing to us to know that his interest in all matters geological continued to the last, and that so long as he was able he beguiled his leisure hours by naming and arranging his small geological cabinet, which was almost entirely the fruits of his own collecting.*

In conclusion, I have to ask you to pass a vote of condolence with Mr. Coutts' widow and family, with an expression of our regret at the loss they have sustained, and also that our Secretary should send an extract from the minutes to Mrs. Coutts.

* Since the date at which this paper was read, Mr. Coutts' cabinet has passed into the possession of the Museum of Science and Art, Edinburgh.

No. XVII.—Notes on some of the Principal Geological Papers at the British Association Meeting, Aberdeen, 1885.

By James B. Murdoch, F.R.Ph.S.E., *Hon. Sec.*

[Read 14th January, 1886.]

[Summary.]

After giving a short account of the more important papers submitted to Section C. (Geology), Mr. Murdoch referred to those bearing on two subjects which were of more than usual interest, viz., the age of the Elgin Sandstones and the succession of the North-West Highland Rocks.

The papers which introduced the former subject were—"The Elgin Sandstones," by Mr. J. G. Phillips, keeper of the Elgin Museum; and "On a new Reptile from New Spynie," by Dr. R. H. Traquair, F.R.S.E., Museum of Science and Art, Edinburgh.

Curiously enough, these Yellow Elgin Sandstones had been a subject of great contention at the previous meeting in Aberdeen—that of 1859—and now their age, which had been thought to be then finally settled, again came up for discussion at the meeting of 1885.

Up till 1852 there had been no question that these rocks were of undoubted Old Red Sandstone age, but in that year Mr. Patrick Duff of Elgin discovered in them the remains of a lizard (*Telerpeton*), while in 1859 Prof. Huxley found in the collection of the Rev. Dr. Gordon of Birnie, from the same strata, crocodilian remains (*Stagonolepis*) and those of another lizard (*Hyperodapedon*); and at the recent meeting Dr. Traquair reported the discovery of another form of lizard (which he named provisionally *Dicynodon*). The discovery of these reptilians, all of Triassic age, was supposed to finally settle the question, and the Elgin sandstones were therefore classed as belonging to the New Red formation, when lately in the same horizon, that of Cutties Hill Quarry near Elgin, Dr. Gordon of Birnie found fish remains (*Holoptychius*) almost in juxtaposition with those of the lizards.

Prof. Judd, in his presidential address, after referring to these finds and the previous state of the controversy, said that "the yellow sandstones, with reptilian remains, clearly overlie the undoubted Upper Old Red, and are separated from it by a well-marked bed of conglomerate. In other quarries in the district the manner in

which these two series of strata have been thrown side by side by the action of great faults is very clearly exhibited." And again—"By a complicated series of parallel faults, the Devonian and Triassic Sandstones, which happen to have a general resemblance in their mineral characters, are found again and again thrown side by side with one another in the Elgin district, so that the error into which geologists fell before the discovery of the distinctive fossils of the two sets of rocks was a very pardonable one."

You will see from this that in Prof. Judd's opinion there was no loophole nor room for doubt; but not so thought Mr. Phillips, curator of the Elgin Museum, who read a long paper on the whole question as seen from a very different standpoint. He expressed his strong conviction, based upon a long and constant acquaintance with the strata worked at Cutties Hill, that there was no unconformability in the sections of the strata exposed, and that therefore it still remained to be proved, to say the least, that the upper or reptilian-bearing beds were not Upper Old Red. He admitted that the palæontological evidence was to some extent against this view, but then it was merely negative, while the stratigraphical evidence was, he asserted, quite in favour of it. He therefore urged strongly that the question should not be considered as decided till further evidence was searched for, and, if possible, obtained.

The subsequent discussion on these papers excited great interest in section C, and the President of course upheld the views generally expressed in his address. He said that though he agreed with Mr. Phillips' presentation of facts, he utterly dissented from his deductions. "It was altogether outside the experience of palæontologists to find reptiles in Old Red Sandstone. They might as well expect to find heather growing between tide-marks, or lilies on the tops of mountain ranges." Here there were found no less than four orders of reptiles, all peculiar to the Triassic period, while no reptile, with one exception (and that a doubtful one), had ever been discovered so low even as the Carboniferous rocks. It would require the strongest evidence to make him believe such would ever be found in Old Red Sandstone; and he might add that, for his own part, he would "require to see a *Holoptychius* in the mouth of a reptile" before he could be convinced.

One of the concluding excursions of the meeting was taken to Elgin, and as my homeward route lay in that direction, I formed

one of the party, which, though a very large one, was most nobly entertained by the authorities and principal residents of the district. One detachment was taken to visit Cutties Hill Quarry, where a fresh trench had been cut below the present floor of the workings to the point of junction of the two disputed beds. The trench was unsatisfactorily narrow, but, so far as could be seen, though the two beds were unconformable, the points of mineral difference were apparently very small. Prof. Judd, Prof. Bonney, and other geologists of note, were to have a more exhaustive inspection on the following day, accompanied by Mr. Phillips and Dr. Gordon, of Birnie ; but it is not within my knowledge whether they satisfactorily adjusted their differences of opinion or not.

The papers on the Highland Rocks were "The Great Highland Controversy : its Causes, Course, and Consequences," by Prof. C. Lapworth ; "The Geology of Durness and Eriboll, with special reference to the Highland Controversy," by Messrs. B. N. Peach and John Horne, of the Geological Survey ; and, though more indirectly, "Some examples of Pressure Fluxion, in Pennsylvania, U.S.," by Prof. H. Carvell Lewis ; and "Notes on some Traverses of the Crystalline Districts of the Central Alps," by Prof. T. G. Bonney.

Before referring directly to the papers of Prof. Lapworth and Messrs. Peach and Horne, it will be well to give you a short summary of the main question at issue.

About the year 1820 Dr. John Macculloch, "that distinguished pioneer in Scottish geology," as Prof. Judd characterized him, asserted that in the Western Highlands there was a great formation of Red Sandstones and quartzites, both showing traces of sedimentary origin, and that associated with them were beds of limestone, with occasional fossils. He further said that this formation was far older than the Old Red, and gave it the name of the *Primary Red Sandstone*. He also showed that these rocks were often found resting unconformably upon the gneissose and schistose rocks of the Highlands, while elsewhere they were found to be overlain by, or to alternate with, crystalline schists and gneisses. He also found organic remains in the quartzites of this Primary Red Sandstone, and identified some of them as the tubes of marine worms, and others as *Orthoceratites*.

Murchison and Sedgwick next visited the district in 1827, and,

objecting to Macculloch's definition and classification, maintained that his Primary Red Sandstone was merely an outlying portion of the true Old Red Sandstone.

In 1839 R. J. H. Cunningham published a geological essay on Sutherlandshire, in which he strongly supported Macculloch's views, and even brought forward some additional evidence in its favour bearing upon points of detail.

In 1854 Charles Peach discovered, in the debated formation, fossils which afforded undoubted evidence that they belonged to an early Palæozoic age.

In 1855, at the Meeting of the British Association in Glasgow, Sir Roderick Murchison admitted that the limestone of Durness, in which Mr. Peach had found his fossils, was of Silurian age, but at the same time defended his old views that the red sandstones were true Old Red; and in this he was supported by Prof. Sedgwick and other geologists.

In 1856 James Nicol, who, in his "Geology of Scotland," published in 1844, suggested the probability of the Highland schists and gneisses being simply altered shales and greywackes, revisited the debatable ground, and was able, as the result of his investigations, to confirm completely the conclusions of Macculloch and Cunningham, that the red sandstone belonged to an older formation underlying the quartzite and limestone. But he divided it into two—the lower, the Torridon Sandstone, lying unconformably on the gneisses, and the upper, consisting of quartzite, and limestone with fossils, resting unconformably upon and overlapping the sandstones.

Nicol continued his investigations during 1857-8-9, and in the latter year, at the Meeting of the British Association in Aberdeen, he finally enunciated his views concerning the question in dispute, and which may be summarized as follows:—

(1) He maintained that there exists in the N.-W. Highlands an enormously thick series of red sandstones, quartzites, and limestones, which rest unconformably upon the old gneisses and schists, and are much older than the Old Red Sandstone.

(2) That the repeating beds of quartzite and limestone are due to faulting and overthrow, and that Murchison's upper quartzites and limestones have thus no existence.

(3) That the supposed conformable upward succession of an older Palæozoic formation into overlying schist and gneiss is due

to the thrusting of the crystalline rocks over the sedimentary ones by great overthrow faults ; and

(4) That the relations between these crystalline and sedimentary strata were precisely similar to those constantly produced by lateral pressure in all great mountain chains, and consist of sharp foldings, inversion and faulting, on the very grandest scale.

These views of Nicol's were not generally accepted till long after this date, such observers as Harkness, Ramsay, A. Geikie, and Hull, throwing their weight into the opposite scale. Gradually, however, and principally within the last seven or eight years, fresh investigations have been made by Hicks, Judd, Bonney, and lastly by Prof. Lapworth and Messrs. Peach and Horne. These have one and all corroborated in the strongest manner the conclusions come to by Nicol, and the veteran geologist's views, which he never doubted would ultimately prevail, are now accepted by the geological world. In justice to Dr. Arch. Geikie, it should not be forgotten that he has had lately the manliness and courage to come forward and make a full recantation and retractation of his former views.*

Prof. Lapworth in his paper spoke of the discoveries of Heim and Lehmann on the Continent, and of their bearings on the question at issue with regard to the geological structure of Durness and Eriboll, which was due largely to vast mechanical changes such as up to this time we had no idea of. "The old stratigraphical rules of research begin to fail us here ; we have to start from a new and totally different standpoint. In the sedimentary world superficial agents bring about the eternal flux of change and modification ; in this new metamorphic world the agents of change are subterraneous. In the sedimentary world water is king. This newly-discovered world is ruled by a despot —the irresistible crush-creep lateral pressure, of whom we know absolutely nothing."

Messrs. Peach and Horne's paper gave an outline of the districts of Durness and Eriboll, and spoke of the existence of a series of reversed faults, which culminate in a great dislocation, bringing up the Archæan gneiss. Reference was made to the effect of this mass of gneiss on the underlying Silurian rocks. It was stated that the foliation of the eastern schists is the result of vast mechanical movements which took place after the Lower

* *Nature*, November 13, 1884.

Silurian time, and that the crystalline character which the Archæan, Cambrian, and Silurian strata possess to the east of the great thrust-planes is due to shearing and re-crystallization. Applying the knowledge thus gained from the study of the eastern schists to the undisturbed Archæan masses, they had found in them evidences of similar mechanical movements. From a consideration of the phenomena they had observed, the authors concluded that regional metamorphism may take place in different geological periods, and that the origin of foliation in areas was that they had been subjected to regional metamorphism or mechanical movement which long afterwards had produced molecular changes in crystalline and plastic rocks.

The subject of the metamorphism of rock masses is one which is slowly but surely taking a prominent place in the consideration of petrology, and it can hardly fail to have an important bearing on the whole question as to the long-obscured origin of our older Highland rocks.

PROCEEDINGS FOR SESSION 1884-85.

(27TH SESSION.)

SOCIETY'S ROOMS, 207 BATH STREET.

16TH OCTOBER, 1884.

Mr. JOHN YOUNG, F.G.S., *Vice-President*, in the Chair.

The CHAIRMAN, in opening the meeting, congratulated the members present that they were assembled to inaugurate the work of the 27th session, and expressed the hope that as the Society had prospered in the past so it would continue to do in the future. Touching on various recent aspects of geological science, he spoke more particularly of the much greater attention given to microscopic and chemical examinations of rocks and fossils, and urged upon all members the necessity of looking at even well-known forms under the new light thrown upon them by modern research.

Mr. JAMES COUTTS exhibited a specimen of *Fissodus Pattoni*, Etheridge, jun., a Fish Tooth from the lower limestone series of East Kilbride; also a specimen of *Ceratiocaris Pattoni*, Peach, a crustacean previously exhibited at a meeting of the Society, but then wrongly named *Palæocaris*, sp. [See *Transactions*, vol. vi., pt. 2, p. 304.] Both specimens were named after Mr. Andrew Patton, *Cor. Member*, East Kilbride, and were from his collection.

Mr. GEORGE R. ALEXANDER exhibited a symmetrically globular nodule found in sandstone near Bothwell, and evidently the result of chemical segregation.

Mr. JAMES WHITE read a paper entitled "A Glimpse of Skye, with Remarks on Volcanic Action" [see p. 105], which was illustrated by specimens of rocks from the district. At its close remarks were made by the Chairman, Mr. William Jolly, F.G.S., and others.

The CHAIRMAN (Mr. Young) then read a paper by himself and Mr. D. C. GLEN, F.G.S., entitled "Note on the Cathkin 'Osmund Stone' (a Volcanic Tuff)" [see p. 133], exhibiting different varieties of the mineral, of which sections were placed under the Society's microscope.

Society's Rooms, 207 Bath Street.

Annual General Business Meeting.

13th November, 1884.

Mr. David Forsyth, M.A., B.Sc., *Vice-President*, in the Chair.

The Hon. Secretary (Mr. Murdoch) read the Report of the Council for the past year as follows :—

The Report of the Council for Session 1883-84.

In accordance with the custom of previous years the Council beg to lay before the members their Annual Report on the business of the preceding session, the 26th in the Society's history. During the year the work has not been characterized by any events of special importance, but has moved on in a calm, satisfactory manner.

The Membership continues at about the average of late years, the number on the roll at the end of the session being—Ordinary members, 200; honorary members, 13; honorary associates, 8; corresponding members, 20; or a total of 241. The vacancies arising from various causes have been perhaps rather in excess of previous years, and the Council hope that members will see their way to enlist many of their friends—a promise of which is well shown by the billet of this evening, where no less than six new members are entered for election. One life member was elected during the year, but this is a source from which additional strength might be largely taken.

Of the Meetings of the Society, nine were held between October, 1883, and May, 1884, the attendance of members being always fair, but by no means so large as the interest of the material brought forward sometimes warranted. Various papers of value and interest were read and discussed, and numbers of specimens were shown, often accompanied by remarks which might have been characterized as "papers." Indeed, as a rule, there was rather an excess of subjects to occupy the time available at each meeting.

Amongst the papers may be mentioned, "Random Notes on the English Lake District," by James White [see vol. vii., p. 334]; "Notes on the Occurrence of *Favosites* (?) (*Calamopora*) *dentifera*, Phillips," by John Young, F.G.S. [see vol. vii., p. 369]; "Geological Notes from the Land of Lorne," by Dugald Bell; "Geological Observations in the Parish of East Kilbride," by Andrew Patton, *Cor. Mem.*, with a list of Fossils compiled by James Coutts [see vol. vii., p. 309]; "The Silurian Rocks of the Girvan District," by David Forsyth, M.A., B.Sc. [see vol. vii., p. 358]; "Review of the Southern Silurian Question," by Arthur Maconnochie, collector to the Geological Survey [for a summary see vol. vii., p. 370]; "Notes on a Fossiliferous Shale near Cloch Lighthouse," by Thomas Scott [see vol. vii., p. 462]; "Preliminary Investigation into the Geology of Benderloch," by W. Anderson Smith, Ledaig; "The Silurian Districts of Leadhills and Wanlockhead," by Dr. J. R. S. Hunter, *Hon. Mem.* [see vol. vii., p. 373].

The Excursions which took place during the spring and summer of 1884 were as follows :—

To Cathkin, Saturday, 7th April, conducted by Mr. Walter Burns.
,, Dumbarton, 26th April, conducted by Mr. John Young.
,, Paisley, 10th May, conducted by Mr. M. Blair.
,, Glen Messan and Benmore, Queen's Birthday, 22nd May, conducted by Mr. D. Wilson.
,, West Kilbride, 7th June, conducted by Mr. Dugald Bell.
,, Dalry, 21st June, conducted by Mr. John Smith.

These excursions were, as a rule, successful, but an exception was the Queen's Birthday trip, which was, in point of attendance, a miserable failure. The Council think that probably the time has come for discontinuing this excursion, as the facilities for reaching all parts of the country on the Queen's Birthday are now so great that members can hardly be expected to turn out in sufficient numbers to make it necessary to organize any special trip on that day. It has sometimes been urged that the Saturday afternoon excursions are too frequently arranged to old and familiar places, but it must not be forgotten that there is great difficulty in selecting places of geological interest which are new ground to most members, and which, at the same time, are accessible from the city in the course of a spring or early summer afternoon. Members who can suggest localities suitable for afternoon excursions would confer a favour on the Council by writing on the subject to the Hon. Secretary.

An excursion to Ailsa Craig, in company with the members of the Kilmarnock Philosophical Society, was organized for 5th June, and a large party of members availed themselves of the unusual opportunity of visiting the lonely rock.

A joint excursion with the members of the Edinburgh Geological Society was arranged to visit the line of the new Edinburgh Suburban Railway on 5th July, under the guidance of Mr. John Henderson, and proved a most interesting one to those who took part in it. The deep cuttings made through the Lower Carboniferous strata and Intrusive Traps were minutely inspected, and some most instructive sections were met with. The joint party afterwards dined together in the Waterloo Hotel, Edinburgh.

The Library continues to prosper, and on its work Mr. Sommerville, the Hon. Librarian, will submit a report. The Council, however, regret to announce that he has found the continuance of the duties incompatible with increasing business engagements, and has therefore asked that a successor be elected this evening. Members will certainly award Mr. Sommerville a hearty vote of thanks for his past services.

Of the "Transactions" vol. vii., pt. 2, is now at press, and will, it is hoped, be ready for issue very shortly. This will bring the printing of papers up to the conclusion of the past session.

Microscope.—By the generosity of Bailie John Farquhar, one of our life members, a handsome petrological microscope was presented to the Society for the use of the members. It was constructed by Messrs. Swift & Son, of London, the well-known instrument makers, and promises to be a credit

to its makers as well as to Bailie Farquhar and the Society. A number of accessory appliances were purchased by the subscriptions of several members. From time to time, as the need is felt, other items will doubtless be added. To the donor of the microscope and to the subscribers to the fund the thanks of members are heartily due.

Loss of Members.—One paragraph in this report can never, unfortunately, be omitted, that in which the loss of members has to be recorded. Noticeable amongst others during the year was the death of Dr. John Dougan, a member of Council, and from a very early date a member of the Society. Soon after its formation Dr. Dougan interested himself in its work, and became a most regular attendant at the meetings.

One of the Society's prominent members, Dr. J. J. Dobbie, having received the appointment of Professor of Chemistry and Geology in University College, North Wales, had to sever his intimate connection with us, and, although able to congratulate Dr. Dobbie on his appointment, the Council cannot help expressing their sense of the great loss his absence from the meetings of the Society involves.

In bringing this report to a close the Council would reiterate a wish that in the future, as in the past, the Society will continue to prosper, and that harmony and good feeling may ever prevail amongst its members.

James Barclay Murdoch, Hon. Sec.

The Hon. Treasurer (Mr. Wight) read his Report as follows:—

Report by the Treasurer for 1883-84.

Your Librarian (Mr. Sommerville) is of opinion that the property of the Society at this time may be taken at the valuation of last year, to which is to be added the microscope and accessories. The Society's stock is therefore £523 17s. 8d., against £452 14s. 11d. reported a year ago, but the expense of printing the year's *Transactions* has to be taken into account as a deduction from stock. This will leave £473 17s. 8d. as the present value of stock, the difference between which sum and the stock of last year is as nearly as may be represented by the value of the microscope.

The Treasurer reported last year 149 subscriptions and £2 10s. of arrears, besides 8 new members, in all 162. This year he acknowledges 150 subscriptions, and £2 10s. of arrears, besides 15 new members, in all 170—being a gain over last year of 8 members. The income has therefore increased by £4 from subscriptions. The capital of the Life Membership Fund has been increased by £5 5s., and it now stands at £120 15s., the income from invested funds being nearly £10 per annum.

Receipts from Subscriptions have amounted to,				£90	5 0
Do. from Interest,				9	15 10
Do. from Publications sold,				7	2 3
Total,				£107	3 1
The *Transactions* have cost,	£91	15	6		
The ordinary expenses of administration,	59	8	10		
				151	4 4
Difference.				£44	1 3

This difference has been paid out of cash in bank on deposit receipt, which last year was £56 and is now only £2.

It is probable that if the current income amounts to £100, and it is almost certain to do so, it will meet the expense of ordinary management, and also the expense of printing last year's *Transactions* if not more than £50. The Society's finance is now, therefore, in such a position that each year's income may be appropriated by each year's expenditure without being mixed with previous years, and this is a state of matters it is very desirable should continue.

JOHN WIGHT, Hon. Treasurer.

The HON. LIBRARIAN (Mr. Sommerville) gave his Report on the state of the Library as follows :—

REPORT ON THE LIBRARY, 1883-84.

I have much pleasure in reporting that the Library has, as in previous years, been well taken advantage of by the members. The newer books have especially been much sought after, and this is not to be wondered at when we consider that geological science is so progressive. The older works are, of course, still found of use, but more historically than otherwise.

There can be little doubt that the want of a catalogue prevents the Library being used to the extent it ought to be. The difficulty in accomplishing this matter is greater than those unacquainted with the details may imagine. There are in the collection several hundreds of volumes treating generally of the science, and a catalogue of these could easily be made and arranged. But there is a mass of valuable papers on geological details scattered through the Transactions and Proceedings of Societies, and to make these available for the use of members who are studying any particular subject they should be catalogued and classified, a work which would be vastly more useful than merely the cataloguing of the 200 or 300 volumes.

Few books were purchased during the past session, but donations of volumes and papers were made by Professor Rupert Jones, Dr. Hunter, Mr. Glen, Mr. Young, Mr. Thomson, and others. Exchanges with other societies still continue, the most noteworthy additions from this source being those from America. I have great pleasure in making special reference to the excellent monograph on the Grand Canon District, by Captain Dutton ; also to the admirable Reports on the Geology of the United States, by Major Powell, and the Geology of the State of Wisconsin, by Mr. Chamberlain. As no part of the *Transactions* was issued this year my work was considerably lighter than it had been in the two previous ones.

The sale of back parts of our *Transactions* brought in £7 2s. 3d., and the total amount received from this source during my three years' term of office has been no less than £21 9s. 4d., after deduction of the usual 25 per cent. discount.

In taking leave of my office I have to thank the Council and the members for their indulgence extended to me. My spare time has been so limited that I have been unable to devote to the Library the attention which I wished to give and which it deserved to receive.

JOSEPH SOMMERVILLE, Hon. Librarian.

The election to fill, for three years, the vacancies occurring amongst the office-bearers was then proceeded with, with the following results :—

As President, Sir William Thomson, F.R.S., etc. ; as Vice-President, Mr. D. C. Glen, F.G.S. ; as Members of Council, Mr. Dugald Bell, Mr. William Armour, Mr. John M. Campbell, and Mr. James Anderson ; as Hon. Secretary, Mr. James B. Murdoch, F.R.Ph.S.E. ; as Assistant Hon. Secretary, Mr. Gavin M. Pratt ; as Hon. Treasurer, Mr. John Wight, C.A. ; and as Hon. Librarian, Mr. James White.

The election of Mr. White as Librarian having left a vacancy in the Council Mr. Matthew Blair was elected for two years.

The following gentlemen were elected Ordinary Members of the Society :—Mr. Charles C. Bone, C.E., 23 Miller Street ; Mr. Robert Gill, 117 West George Street ; Mr. John Howat, 363 New City Road ; Mr. J. B. M'Donald, C.E., 74 Hutcheson Street ; Mr. William Petrie, 17 Steven Street ; Mr. George W. Walker, 10 Airlie Terrace, Pollokshields.

Mr. ROBERT DUNLOP exhibited, with remarks, a number of fine specimens of Fossil Fish remains from the Airdrie shale beds in the Upper Carboniferous series, including *Ctenodus cristatus* and *C. obliquus*. Mr. JAMES THOMSON, F.G.S., and Mr. JOHN YOUNG, F.G.S., also made some observations.

Mr. JAMES COUTTS exhibited specimens of Spines of *Ctenacanthus*, *Homocanthus*, and *Leptacanthus*, also *Orthoceras subcentrale*, all from the cement limestones of East Kilbride, and in the collection of Mr. A. Patton.

Mr. D. C. GLEN, F.G.S., *V.P.*, read some notes on his recent trip to Canada and the United States to attend the Meeting of the British Association at Montreal, and exhibited a number of mineral and rock specimens of interest illustrative of his remarks.

SOCIETY'S ROOMS, 207 BATH STREET.

11TH DECEMBER, 1884.

Mr. D. C. GLEN, F.G.S., *Vice-President*, in the Chair.

Mr. DAIRON read a report upon the Society's Collection of Specimens, with a scheme for its re-arrangement, upon which Mr. James Thomson, F.G.S., made some remarks. After some discussion the subject was postponed for further consideration.

Dr. J. J. Dobbie, Professor of Chemistry and Geology, University College, North Wales, was elected a Corresponding Member ; Mr. J. J. Alexander, 43 West Regent Street ; Mr. Thomas Davidson, 41 St. Enoch

Square; and Mr. William Simmons, 70 Forth Street, East Pollokshields, were elected Ordinary Members of the Society.

Mr. Robert Dunlop exhibited specimens of *Cœlacanthus lepturus*, from the shales of the Airdrie Upper Carboniferous series, and made some remarks upon its occurrence, as did also several other members.

Mr. James Thomson, F.G.S., exhibited a number of fine specimens from various localities in the United States, showing crystalline structure, and read a series of notes on a trip he had made through the territory of Idaho, to the mining region of Atlanta Mountain, during the past autumn. [For a summary see page 173.]

Mr. John Young, F.G.S., *V.P.*, exhibited specimens of Brucite, a native hydrate of magnesia. This mineral is found filling veins in a serpentine rock at Swenee Ness, Balta Sound, Unst, Shetland, and is of a pale sea-green colour, with a pearly lustre. It is transparent and soft, and splits into thin laminæ, which are flexible. It is composed chemically of 69·75 parts of magnesia with 30·25 of water, and is the purest native condition of the mineral which is known. It is rather rare, and only some eight or nine localities are as yet given for it, that of the specimen shown being one of the oldest and best known. Brucite is believed to be derived from the magnesian element which enters into the composition of the serpentine rocks, and which, dissolved out by water passing through them, and carried into fissures, assumes its pure crystalline form. The specimens exhibited were presented to the Hunterian Museum by Mr. J. H. Fullarton, M.A., B.Sc.

Mr. Matthew Blair read a paper entitled "Notes of a Visit to the Prairies and Rocky Mountains of Canada."

Mr. Blair's paper was illustrated by a fine Geological Map of Canada, presented to the Society by the Geological Survey of Canada, through Mr. James Thomson, F.G.S.

Society's Rooms, 207 Bath Street.

8th January, 1885.

Mr. John Young, F.G.S., *Vice-President*, in the Chair.

Mr. William Macrone, 28 St. Enoch Square, and Mr. Edward Westwood, 137 Ingram Street, were elected Ordinary Members of the Society.

Mr. Joseph Sommerville moved that a sum of £10 from the Society's funds be devoted to the purposes of the Library, which was unanimously agreed to.

Mr. Robert Dunlop exhibited several species of Fish from the Airdrie shale beds, also several from the Carboniferous strata at Annick Lodge, Ayrshire. The only new species seemed to be one of *Megalichthys*, which had been seen by Dr. Traquair, but had not yet been determined.

Mr. Robert Craig, Langside, Beith, *Cor. Member*, exhibited specimens of teeth of *Rhizodus* from the Clayband Ironstones of the Beith Carboniferous series, and of very unusual size. Some remarks on these interesting

specimens were made by the Chairman, by Mr. James Thomson, F.G.S., and others.

The Chairman (Mr. Young) exhibited specimens, sent by Mr. George Lamb, of Silurian Schist of the Bala series, from Dolgelly, North Wales, and which contained an appreciable quantity of gold.

Mr. Robert Craig, Langside, Beith, *Cor. Member*, read a paper "On the Upper Limestones of North Ayrshire" [see page 28], illustrated by a sectional map of the district.

Mr. James Thomson and the Chairman made some remarks on the subject of this paper, congratulating the Society on the reception of another valuable paper from Mr. Craig regarding a district he had made so thoroughly his own.

Mr. D. C. Glen, F.G.S., exhibited under the Society's microscope specimens of Star Mica (*Phlogopite*) from Canada, remarking that, so far as he knew, the peculiar characteristics of the mineral, which he pointed out, were not described in any of the text-books, but had been recently illustrated and described by a writer in *Science Gossip*.

Society's Rooms, 207 Bath Street.

12th February, 1885.

Mr. David Forsyth, M.A., B.Sc., *Vice-President*, in the Chair.

Mr. J. H. Fullarton, M.A., B.Sc., Natural History Rooms, University of Glasgow, was elected an Ordinary Member of the Society.

Mr. Robert Dunlop exhibited a further selection from his collection of Fish Remains from the Airdrie shale-beds, with remarks, which were supplemented by Mr. John Young, F.G.S., and Mr. James Thomson, F.G.S.

Mr. Daniel Wilson exhibited samples of Copper-bearing Rocks from Aberystwith, Cardiganshire, North Wales, some of which contained by assay about 28 per cent. of copper, and therefore compared favourably with the recent produce of Cornish lodes.

Mr. John Kirsop, F.S.A.Scot., exhibited, with remarks, a fine series of remains of Fossil Fish from the flagstones of Caithness, belonging to the Lower Old Red Sandstone group. Of these Caithness flags Sir Richard Owen once wrote that they owe their peculiar and valuable qualities of density, tenacity, and durability, wholly to the dead fish that rotted in their primitive mud. Mr. Kirsop also exhibited a beautiful specimen of a Fossil Fish from Ottawa, Canada, by the kindness of Mr. Spence Bates, of Plymouth, but the genus and species were undetermined.

Mr. John Young, F.G.S., gave some explanatory particulars regarding these specimens of fish.

Mr. Matthew Blair exhibited a specimen of the Prairie Coal of North-West Canada, said to be of Tertiary age, its range extending over hundreds of miles; also a specimen of Carboniferous Coal from New Glasgow, Nova Scotia, where the seam is 18 feet in thickness. New Glasgow, Mr. Blair said, is at present only a small town, but from its

proximity to great mineral wealth, it is evidently destined to become at no distant date a place of importance. Judging from the names over the shops, he could almost have believed himself to be in *Old* Glasgow.

Mr. DUGALD BELL read a paper entitled "Notes on some Recent Excursions of the Society," in which he touched upon a number of interesting points in connection with various of these gatherings. He remarked incidentally that he thought it would be a feature of interest, if, as a matter of course, the excursions were recorded and shortly described during the session following their occurrence. Mr. Bell's paper was illustrated by several sheets of the Geological Survey map.

Mr. JOHN KIRSOP submitted, for the consideration of the meeting, the theory advanced by Prof. Cope Whitehouse, of the United States, that Fingal's Cave, Staffa, is not of natural, but of artificial origin. It was, however, thought to be too absurd to permit of discussion.

SOCIETY'S ROOMS, 207 BATH STREET,
12TH MARCH, 1885.

Mr. D. C. GLEN, F.G.S., *Vice-President*, in the Chair.

Mr. Loudon M. Douglas, Chemist, 20 Canal Bank, was elected an Ordinary Member of the Society.

Mr. JOHN KIRSOP, F.S.A.Scot., exhibited various Mammalian Remains from the phosphate deposits of Beaufort River, U.S., comprising Teeth of *Mastodon*, *Elephas*, and one or two Ruminants; Bones belonging to the same group, and a fragment of Deer's Horn.

Mr. JOHN YOUNG, F.G.S., remarked that the fact that such remains were found largely intermingled with marine organisms showed that they must have been brought down by the action of some great river from land existing at the time when these now extinct animals lived.

Mr. JOHN YOUNG read a paper on the remarkable structure known as "Cone-in-cone." [See page 1.] An interesting discussion on Mr. Young's paper was taken part in by Messrs. Thomson, Forsyth, Anderson, Bell, Murdoch, and others. Most of the speakers thought that Mr. Young's theory was reasonable and natural, and that therefore he had contributed more towards the dispelling of the obscurity attending the formation of Cone-in-cone than any previous observer.

SOCIETY'S ROOMS, 207 BATH STREET,
2ND APRIL, 1885.

Mr. JOHN YOUNG, F.G.S., *Vice-President*, in the Chair.

Some remarks on the question of accommodation of the Museum were made by Mr. James Thomson, F.G.S., after which it was formally moved

and agreed that the Committee be thanked for its labours and discharged, and that no further action in the matter be taken in the meantime.

Mr. William Muir, 3 North Street, Anderston, and Mr. Hugh Wilson, 35 Raeberry Street, were elected Ordinary Members of the Society.

Mr. Robert Dunlop exhibited a large series of Plant Remains from the Carboniferous shales of the Airdrie district, and read a paper descriptive of them by Mr. Robert Kidston, F.G.S., Stirling. [See page 47.] Several of the genera and species were new to Scottish strata.

Mr. John Young, F.G.S., Vice-President, exhibited specimens of Actinolite and Anthophilite which he had received for the Hunterian Museum from Mr. Arthur Macconochie, Edinburgh, Collector to the Geological Survey. They were obtained in Durness, Sutherlandshire, and were doubtless only varieties of Amphibole or Hornblende.

Society's Rooms, 207 Bath Street,
14th May, 1885.

Mr. D. C. Glen, F.G.S., *Vice-President*, in the Chair.

Mr. William Campbell, Seafield Cottages, Claythorne, Partick, was elected an Ordinary Member of the Society.

Mr. James Coutts read "Notes upon the bed of Intrusive Dolerite exposed in the channel of the Clyde at Elderslie, and the work of its removal." Mr. Coutts' paper was illustrated by specimens of the rock, and cores from the bores put down for blasting purposes, also by a geological map of the district.

Mr. William Jolly, F.G.S., read a paper entitled "The Parallel Roads of Lochaber: the Problem, its Conditions and Solutions." [For a Summary see page 40.] The paper was extensively illustrated by maps, sections, and diagrams.

Society's Rooms, 207 Bath Street,
28th May, 1885.

Mr. David Forsyth, M.A., B.Sc., *Vice-President*, in the Chair.

Mr. Murdoch (Hon. Secretary) gave some explanations as to the forthcoming meeting of the Mineralogical Society of Great Britain in the Society's Rooms, on the 16th of June proximo, and stated that an invitation to be present at the meeting had been given to all members of the Society. Mr. Murdoch also spoke of the arrangements regarding the joint excursion with the members of the Edinburgh Geological Society to Bathgate, on 6th June proximo. He further gave some particulars as to a proposed exchange of specimens of minerals, etc., between members of the Society and Prof. Bombicci, of Naples, which had been arranged by Mr. George R. Alexander on his recent visit to Italy.

Dr. J. R. S. Hunter, F.R.Ph.S.E., *Hon. Member*, read two papers, as follows:—(1) "Notes on the Discovery of a Fossil Scorpion, *Caledonicus Palæophonus*, in the Silurian Strata of Logan Water." [For a Summary see p. 169.] (2) "The Old Red Sandstone of Lanarkshire, with notes on volcanic action during Old Red and Carboniferous Times, with an exhibition of the head of *Cephalaspis Glottensis* from the Lower Old Red Sandstone of Lesmahagow." [See page 161.]

In the course of some remarks by Mr. John Young upon these papers, he suggested that the *Cephalaspis* should be called *C. Lyelli*, variety *Glottensis*.

The Chairman (Mr. Forsyth) also made some observations.

Mr. James Thomson, F.G.S., said that before the meeting closed he wished to be allowed to exhibit a specimen of Limestone taken from a large block in the Borland Burn on the Marnock Water, which showed Cone-in-cone structure. While accepting generally Mr. Young's theory of the origin of Cone-in-cone, as given in his paper read at last meeting, he did not believe that it could account for the presence of radiation of the structure of Cone-in-cone from a centre, as shown in the mass of which the specimen now exhibited formed a part.

Mr. Young, in reply, said that as the specimen Mr. Thomson brought forward did not in itself show the appearance of radiation of Cone-in-cone structure from a centre said to be found in the parent block, he could not accept Mr. Thomson's conclusions without further evidence.

After some discussion, the meeting agreed to defer passing any expression of opinion on the subject in the meantime, and requested Mr. Thomson to bring up at an early meeting in the coming session a larger specimen of the limestone, showing in itself distinct radiation of Cone-in-cone from a common centre.

PROCEEDINGS FOR SESSION 1885-86.

(28TH SESSION.)

SOCIETY'S ROOMS, 207 BATH STREET,

15TH OCTOBER, 1885.

Mr. JOHN YOUNG, F.G.S., *Vice-President*, in the Chair.

The CHAIRMAN said, in opening the first meeting of a new session he hoped and believed that as good work would be done by the members in the future as had been done in the past, and urged that those who were able to contribute papers and specimens for forthcoming meetings should not be backward in bringing them forward, so as to increase the interest of the meetings, and at the same time lighten the work of the Secretaries.

Mr. JAMES COUTTS read "Notice of the late Mr. Andrew Patton, *Cor. Member*, East Kilbride," in which he gave a short account of Mr. Patton's life and work, proposing, in conclusion, a vote of condolence with his widow and family. [See page 171.]

The CHAIRMAN said that he could endorse all that Mr. Coutts had said respecting their deceased friend. He was an ardent and intelligent collector, and a good type of a class to be met with in various localities of the West of Scotland, many of them being men whose natural abilities and tastes had been stimulated and encouraged in the right direction by their intercourse with members of the Society.

Mr. JAMES WHITE read a paper entitled "Notes on Tarbert, Argyllshire." [See page 171.]

Dr. M. F. HEDDLE, of St. Andrews, gave some interesting details regarding various of the rarer Western Scottish minerals, including Edingtonite, Greenockite, Thomsonite, Heulandite, and others, referring more particularly to those of which the localities are at present unknown, and remarking that members who took an interest in mineralogy should not lose any opportunity of re-discovering the lost localities in the cause of science as well as for their own personal advantage.

Society's Rooms, 207 Bath Street,

12th November, 1885.

Annual General Business Meeting.

Mr. D. C. Glen, F.G.S., *Vice-President*, in the Chair.

The Hon. Secretary (Mr. Murdoch) then read as follows :—

The Report of the Council for 1884-85.

Your Council have again the pleasure of laying before the Society their annual report on the work of another session, and are glad to be able to speak favourably of the past and hopefully of the future.

The Membership has during the year gone by remained at about its recent level, the number of deaths and resignations being nearly balanced by the accession of new members. Though this state of matters is so far satisfactory, yet the Council would rejoice to see an increase in the roll of membership, and therefore express a hope that every individual member will do his best to add to the number.

The Finances are, as your Hon. Treasurer will inform you, in a sound and healthy condition.

The Meetings of the past session were nine in number, and were attended by quite the usual average—about one-fourth of the total membership—which, taking into account the many attractions now-a-days held out for evening amusement or instruction, may be considered as a remarkably good one.

The Papers and Specimens submitted to the meetings were, as a rule, of much interest. Amongst the former may be enumerated the following :—"Another Glimpse of Skye," by Mr. James White ; "Notes of a Visit to the Prairies and Rocky Mountains of Canada," by Mr. M. Blair ; "The Upper Limestones of North Ayrshire," by Mr. Robert Craig, *Cor. Member* : "Notes on Recent Excursions of the Society," by Mr. Dugald Bell ; "On Cone-in-Cone Structure," by Mr. John Young, F.G.S., *V.P.* ; "On Plant Remains from the Airdrie Shales," by Mr. Robert Kidston, F.G.S. ; "On the Parallel Roads of Lochaber : the Problem, its Conditions and Solutions," by Mr. William Jolly, F.G.S. ; "Notes on the Discovery of a Fossil Scorpion in the Silurian Strata of Logan Water" and "The Old Red Sandstone of Lanarkshire," by Dr. J. R. S. Hunter, *Hon. Member*. Most of those papers will, it is hoped, be printed along with these of the present session in the forthcoming part of the Society's *Transactions*, which is now preparing for press.

The Excursions of the session were as follows :—

To Arkleston, Paisley, on Saturday, 18th April, conducted by Mr. M. Blair.

To Boyleston, Barrhead, on Saturday, 2nd May, conducted by Mr. D. C. Glen, F.G.S.

To Corrieburn, on Saturday, 16th May, conducted by Mr. John Young, F.G.S., *V.P.*

To Trearne, Beith, on Saturday, 30th May, conducted by Mr. Robert Craig.

To Lochlomondside, on Saturday, 13th June, conducted by Mr. Dugald Bell.

They were all well attended, some of them numerously so. Perhaps the last-mentioned was the one most appreciated, partly on account of its greater novelty, being made to a locality not previously visited by the Society. On this occasion the party was hospitably entertained at Arden House by Mr. James Lumsden, F.Z.S.

A Joint Excursion with the members of the Edinburgh Geological Society, now considered to be one of the standing events of the year, was arranged to be made to Bathgate on the 5th June, under the leadership of Mr. John Young, F.G.S., but in his unavoidable absence from indisposition, Mr. James Bennie of the Geological Survey conducted the party. The very enjoyable day was wound up by a dinner at the Bathgate Royal Hotel.

Another excursion, and one inaugurating quite a new departure, was one arranged to take place jointly with the members of the Edinburgh Geological Society to Lochaber and the Parallel Roads of Glen Roy, during the last week of July, under the leadership of Mr. William Jolly, F.G.S. It extended over a full week, and of the twenty men who took part in it not one had reason to look back upon it with anything but pleasurable feelings. During the six days at the disposal of the party much ground was gone over and many interesting facts were brought under notice. First an ascent of Ben Nevis at night and descent in the early morning, and secondly a close inspection of the wonderful "Roads" and the splendid glaciation of the district. Before the party broke up a wish was generally expressed that similar excursions might in future years be organized to other districts of geological interest.

The Library has during the past year been considerably added to, both by donation, exchange, and purchase. Great progress has also been made in bringing it into good working order, as will be seen from your Hon. Librarian's Report, to be submitted this evening.

Of the Transactions, a new part, the largest yet issued, was sent out to members early in the past summer. That to follow (Part I of Vol. VIII.) is just preparing for the printer, and will contain the papers of last session, as well as those of the present one.

The Death of Members.—As is unhappily usual in this Report your Council have to note the loss of several members more or less prominent in the Society's work. Mr. Andrew Patton, of East Kilbride, a *Corresponding Member*, whose fine collection of fossils from the Kilbride Cementstone Series has so often been laid under contribution to grace the exhibitions of our meetings, through the agency of Mr. James Coutts, died early in summer, and Dr. Thomas Davidson, of Brighton, one of our *Honorary Members*, whose great work amongst the Brachiopoda is known to every palæontologist, died last month. More than an expression of deep regret at their removal from amongst us need not here be made, as notices of both will appear in the *Transactions*, the former, by Mr. Coutts, having been read at last meeting, while the latter is to be given by Mr. Young in the course of this evening.

Mr. JOHN WIGHT, C.A., Hon. Treasurer, then read as follows :—

REPORT BY THE TREASURER FOR 1884-85.

The income of the Society maintains the steady position it has occupied for a good many years. The last Report exhibited an income from subscriptions of £75 from 150 members on the roll when the session opened, besides £2 10s. for arrears and £7 10s. from 15 new members, in all £85. During the year just ended an equal influx of new members has occurred ; the same sum of arrears has been recovered ; and 150 subscriptions have been paid, in all £86 10s., showing a difference of £1 10s. in favour of the present year. So far, therefore, as ordinary revenue from subscriptions is concerned the Society is maintaining its ground, and that without any particular effort. Last year produced a revenue from invested funds of £9 15s. 10d., which item this year amounts to £10 0s. 5d.

The accounts have now fallen into a methodical shape, and we may compare year by year the two branches of expenditure into which the payments are divided—that is to say, the ordinary normal expenses, and the expense of publications. Last year we paid £59 8s. 10d. for every kind of expense attending management, but that sum must have included more than a year's, perhaps more than two years', expense for printing cards and circulars, because the amount paid under that head was so high as £28 11s. 6d. Everything else was normal, and the Collector's commission, including postages and petty expenses, was £4 8s. 6d. The present year shows a total expenditure of £43 16s. 8d. only under this branch. The Treasurer is desirous, as he formerly remarked, to charge each year's revenue with the same year's expenditure, and it is evident from the figures that this point has now been nearly attained.

The cost of printing the *Transactions* published at the close of last session has not yet been paid, except for lithographing the plates. The amount is past due and will be paid now, and it is entered in the Accounts as a charge against the Society's capital stock ; the other debts, chiefly for printing cards and circulars, are supposed to come within £12. The Society's property, then, is held to be fairly valued at £561 17s. 5d., and after deducting the debts the net amount is £475 3s. 5d. The net stock last year was given up at £483 17s. 8d., a difference of £8 14s. 3d. against the year 1885.

The Treasurer reported last year that he expected the Society's income this year to be £100, and he was nearly right, because it has realized £96 10s. 5d. He also mentioned that if the cost of the *Transactions* then in hand was only £50, ordinary revenue would meet all the expense. But he has shown that the cost is £74 14s., and that the net capital stock of the Society is only £8 14s. 3s. less than the net capital stock of the Society a year ago. It therefore follows that the Treasurer's expectations have been realized beyond the extent of his anticipations, because ordinary revenue has paid for the *Transactions*, not at £50 but at £74 14s., with exception only of this sum of £8 14s. 3d.

The life subscription fund rests at £120 15s.

JOHN WIGHT, Hon. Treasurer.

Mr. James White, Hon. Librarian, then read his Report on the state of the Library for 1884-85, from which it appeared that while a good deal of work had been done much more remained to be done, and some expense would have to be incurred before the Library assumed a satisfactory condition.

All these reports were unanimously approved of and adopted, and a cordial vote of thanks was awarded to the Hon. Treasurer, Hon. Librarian, and Hon. Secretaries for all the time and trouble they had expended on behalf of the Society during the past year.

Mr. White proposed that an additional £10 should be granted for the use of the Library during the present year, and this was unanimously agreed to.

The election of office-bearers was then proceeded with, the result being as follows :—

As Vice-President, Mr. William Jolly, F.G.S.; as Members of Council, Messrs. David Forsyth, Joseph Sommerville, Charles L. Dobbie, and John Farquhar. Messrs. John Robertson and George R. Alexander were re-elected Auditors for the current year.

Mr. James B. Murdoch (Hon. Secretary) exhibited two Caudal Vertebral Bones of a Cetacean, which had recently been dug up from under a bed of peat at a depth of about ten feet, in the neighbourhood of Rumbling Bridge, Perthshire, and from a higher level above the sea than whale remains had previously been discovered at. The species to which they belonged had not yet been determined.

Mr. William Jolly, F.G.S., *Vice-President*, read an account of the joint excursion by the members of the Glasgow and Edinburgh Geological Societies to Ben Nevis and Glen Roy with its Parallel Roads, during the last week of the past July. [See page 72.] The paper was illustrated by a series of maps and diagrams.

Owing to the lateness of the hour discussion on Mr. Jolly's paper, as also a Notice of the late Dr. Thomas Davidson, of Brighton, by Mr. John Young, F.G.S., had to be postponed to the following meeting.

Society's Rooms, 207 Bath Street,

10th December, 1885.

Mr. William Jolly, F.G.S., *Vice-President*, in the Chair.

The following gentlemen were elected members of the Society :—As Honorary Member, Dr. M. Foster Heddle, F.R.S.E., St. Andrews. As Ordinary Members, Mr. John Clark, Gushetfaulds ; Mr. James Hamilton, Mining Engineer, 92 North Frederick Street ; Mr. George E. Henderson, Assistant to Professor of Chemistry, University, 1 Westbourne Terrace, Kelvinside ; Mr. Robert More, Stationer, 505 Sauchiehall Street; Mr. James T. Tullis, The Anchorage, Burnside ; Mr. David Tullis, Glencairn, Burnside.

Mr. J. B. Murdoch (Hon. Secretary) exhibited a specimen of Ilmenite or Titaniferous Iron, a hematite with part of the iron replaced by Titanium, from Arrochar, Loch Long, but only found there in boulders. Mr. John Young, F.G.S., said that when on an excursion last year to the head of the Holy Loch, and on a road near Benmore House, he had found the mineral *in situ*, in vein quartz.

Mr. Young exhibited a specimen of Ambrite or Fossil Resin found in Tertiary coal in New Zealand; also a specimen of "Kauri Gum," a subfossil resin supposed to be derived from pine trees of a bygone time and now found by professional diggers of the substance in the soil of certain localities of New Zealand.

Mr. Young also exhibited a specimen of *Psilotites unilateralis*, Kidston, from Carboniferous Shale raised at one of the coal-pits near Baillieston.

Mr. Young read a notice of the late Dr. Thomas Davidson, of Brighton, more especially as connected with his lifework amongst the Brachiopoda of the West of Scotland, proposing that an expression of condolence should be sent to Dr. Davidson's widow. This was unanimously agreed to. [See page 138.]

The adjourned discussion on Mr. Jolly's paper on the Parallel Roads of Glen Roy, was then taken up, remarks being made by Messrs. Jolly, Young, Renwick, Thomson, Murdoch, and others.

Society's Rooms, 207 Bath Street,

14th January, 1886.

Mr. John Young, F.G.S., *Vice-President*, in the Chair.

The Hon. Secretary read a letter he had received from Dr. Heddle, with a large parcel of his various writings upon Mineralogy, which he begged the Society to accept as a small acknowledgment of the honour done him by his election as Honorary Member. Dr. Heddle further offered to deliver two lectures to members and their friends, "On Carbonic Acid in Nature as illustrative of Design." This offer was warmly accepted, and the Council was asked to make the needful arrangements.

Mr. John Dougan exhibited a specimen of Coal from Langloan, showing a peculiar collapsed spheroidal structure.

Mr. D. C. Glen, F.G.S., *V.P.*, exhibited, with remarks, as follows :—

(1) Kerosene Shale, or Australian "Boghead," from New South Wales.

(2) Schorliferous Granite, from Rubislaw, Aberdeenshire, and Portsoy, Banffshire.

(3) Serpentine and Marmolite (polished), from Portsoy.

(4) Crystals of Greenockite or Sulphide of Cadmium, a slide containing upwards of 30 small crystals, exhibited under the Society's microscope.

Mr. John Young, F.G.S., and other members made explanatory remarks.

Mr. J. B. Murdoch (Hon. Secretary) read a paper entitled "Notes upon the Recent Meeting of the British Association at Aberdeen." [For a Summary, see page 179.]

Mr. William Jolly, F.G.S., *V.P.*, said that, at the late hour of the evening, it would be impossible to go into either of the important subjects touched upon in Mr. Murdoch's paper; but, as regarded the North-West Highlands, he might say that he had been asked to give a paper to the Edinburgh Geological Society, with the view of organizing an excursion to Loch Maree, a district where the disputed rocks could be studied to advantage, in the course of next summer, and that, if the meeting approved, he would be glad to read it before the Glasgow Society also. Mr. Jolly's offer was cordially accepted.

Society's Rooms, 207 Bath Street,

11th February, 1886.

Mr. William Jolly, F.G.S., *Vice-President*, in the Chair.

Mr. John D. Crockatt, mining engineer, Annan Villa, Falkirk; and Mr. James Hugh, clerk, Nelson Cottage, Langside, were elected Ordinary Members of the Society.

Mr. A. C. Macintyre exhibited a fine specimen of Malachite which had been lately found on Croy Hill, Dumbartonshire. How it had reached that locality was, however, a matter for speculation, as it was clearly not native. Mr. John Young said that he thought it had every appearance of being a true Russian or Australian specimen.

Mr. John Buchanan exhibited specimens of Iron Pyrites, Calc Spar, Galena, etc., from Leadhills, Lanarkshire; and on them Mr. John Young, F.G.S., made some interesting explanatory remarks.

Dr. James Thomson, F.R.S.E., Professor of Engineering in the University of Glasgow, read a paper entitled, "On Crystallization and Liquefaction as influenced by stresses in the crystals, with special reference to metamorphic changes in rocks and to plasticity of ice." Professor Thomson explained his theory of crystallization and liquefaction as influenced by stresses that lead to change of form in the crystals. Taking, for example, the case of crystals of ice, he showed that any stresses whatever tending to change the form of a piece of ice in ice-cold water must impart to the ice a tendency to melt and to give out its cold, which would generate from the surrounding water a corresponding quantity of ice free from the applied stresses. This newly formed ice would in due time come to undergo the straining action, and then to melt, the action of glacier ice being thus accounted for.

This theory of the plasticity of ice and the motion of glaciers, Professor Thomson offered in place of his now well-known theory, which he gave in December, 1861, in a paper to the Royal Society (of London), and which many years ago he had almost entirely withdrawn. In the course of his

paper, he submitted for examination, and made some remarks on, the impressed limestone pebbles which, about the year 1862, had been under the careful scrutiny of Mr. H. C. Sorby, as he held that the theory he now presented afforded a satisfactory explanation of their peculiar impressed and indented appearance. Professor Thomson also showed specimens of distorted and metamorphozed quartzite pebbles from the Ballinton beds, near Aberfoyle. Also, a series from Prescott, kindly furnished to him by Dr. Ricketts, F.G.S., Birkenhead, which appeared to have been in a semi-plastic condition, each one having been impressed into its contiguous neighbours. The metamorphic changes in these conglomerates, as also metamorphic changes in many other kinds of rocks, might, he thought, have an explanation applied by means of the theory he had propounded.

Mr. John Young, F.G.S., *V.P.*, Mr. D. Forsyth, and the Chairman (Mr. Jolly) having given expression to their views, Professor Thomson received a hearty vote of thanks for bringing his paper before the Society.

Society's Rooms, 207 Bath Street,

11th March, 1886.

Mr. D. C. Glen, F.G.S., *Vice-President*, in the Chair.

Mr. William Campbell exhibited a Fossil Starfish from the Brick Clay-beds of Jordanhill, and remarked that the Brick-clays of Jordanhill, of which two distinct beds are seen, occupy a hollow in the Boulder-clay averaging about half a mile in breadth, and extending in a north-westerly direction for several miles, the beds at Dalmuir being probably a continuation of them. The upper bed is about 8 feet in thickness, and is reddish in colour, with few or no shell remains, but having a reed-like plant abundantly through it. The lower bed varies in depth according to the undulations in the surface of the underlying Boulder-clay, and is of a deep blue colour. In it shells, many of species still living in our seas, abound, and also the reed-like plant of the upper bed. In one of the lowest layers of this bed Mr. Campbell found the Starfish now exhibited, and thought that it also, like many of the mollusca in the bed, might be of an existing species, but this seems not to be the case, as it does not agree with any of the specimens of recent Starfish in the Hunterian Museum, the most important difference being that, while the plates of recent species terminate in several spines, in this one the spines are entirely absent.

The specimen had been submitted to Mr. David Robertson, F.L.S., who informed Mr. Campbell that he "had not seen one from the Clyde Valley with the outline so well preserved"; and went on to say that, "throughout our Post-tertiary beds, both in the East and West of Scotland, plates of Starfishes are found not uncommonly scattered through the clay; and there is little doubt that some of these scattered plates belong to the same genera or species as the one sent me. This, however, cannot well be ascertained without breaking up the specimen and washing the plates, but it would be a great pity to destroy such a fine specimen."

Mr. James Prentice exhibited a specimen, showing the deposition and crystallization of Bisulphide of Iron on Sandstone, from Messrs. Black's ironstone mines, Stanrigg, Airdrie. It was found in a fissure of the roof of the slatyband ironstone 905 feet from the surface of the ground. Dr. Heddle, Mr. John Young, F.G.S., *V.P.*, Mr. James Thomson, F.G.S., and other members, spoke regarding this interesting specimen.

Mr. Robert Dunlop exhibited a specimen of *Calamitina*, a fossil plant from the Lanarkshire Coalfield, closely allied to *Halonia*.

Mr. John Howat exhibited a series of Carboniferous Fossils, from Poolvash Bay, Isle of Man, some specimens of *Goniatites* being unusually fine. Dr. Heddle, Mr. James Thomson, and other members, pointed out some of the peculiarities of the collection.

Mr. John Young, F.G.S., *V.P.*, read a paper, entitled, "Notes on the Carboniferous Brachiopoda of Scotland, with a revised list of the genera and species." [See page 142.] The paper was illustrated by sections and diagrams, also by type specimens of the genera and species of Scottish Brachiopoda. Dr. Heddle, Mr. James Thomson, and other members, spoke on the subject of Mr. Young's paper, which was characterized as being very exhaustive, and likely to be of considerable use to workers amongst Scottish Brachiopoda.

Society's Rooms, 207 Bath Street,

15th April, 1886.

Mr. John Young, F.G.S., *Vice-President*, in the Chair.

Mr. Walter Steuart, insurance agent, 12 Pollok Road, Pollokshaws, was elected an Ordinary Member of the Society.

The Chairman read a notice he had drawn up regarding the late Mr. James Coutts, one of the active members of the Society, who had been lately removed by death, and proposed that a vote of condolence with his widow should be passed, and an extract from the minutes forwarded to her by the Secretary. This was unanimously agreed to. [See page 177.]

The Chairman (Mr. Young) and Mr. Robert Mason, F.L.S., exhibited specimens of a rare Echinoderm *Allagecrinus Austinii*, Etheridge and Carpenter, from the weathered Limestone shale of Auchenskeoch, Dalry, and Gillfoot, Carluke, accompanied by some remarks by Mr. Young.

Mr. Dugald Bell read a paper entitled "The Detached Areas of Carboniferous Deposits in Scotland," in which he gave a short account of the principal and smaller isolated coalfields so far as known to exist in the northern portion of the kingdom. An interesting discussion followed, and was taken part in by the Chairman, Mr. Forsyth, Mr. James Thomson, F.G.S., and other members.

Owing to the lateness of the hour another paper by Mr. Bell, "Some Notes on the Glaciation of the South of Scotland," was held over to a future meeting.

Society's Rooms, 207 Bath Street,

13th May, 1886.

Mr. D. C. Glen, F.G.S., *Vice-President*, in the Chair.

Mr. Robert M'Laren, H.M. Inspector of Mines, Coatbridge, was elected an Ordinary Member of the Society.

Mr. Matthew Blair exhibited, with remarks, specimens of Beechwood taken from beneath the foundation walls of St. Mirren's Church, Paisley. The logs of beech, of which the specimens exhibited were portions, had in the year 1803 been originally placed where they were found, for the purpose of supporting the building, of which the site was in a soft and boggy situation. The combined moisture and pressure seemed to have considerably altered their structure. Remarks on the interesting questions raised were made by the Chairman (Mr. Glen), Mr. Murdoch (Hon. Secretary), Mr. John Young, F.G.S., and other members.

Mr. William Jolly, F.G.S., *V.P.*, read a paper on "The Succession of Rocks in the North-West Highlands: the Problem, its History and Present State," giving a graphic account of the district and its salient geological features, about which so long and so fierce a controversy has raged. The age and succession of the North-West Highland rocks has now been definitely settled to be those first promulgated by the late Professor James Nicol, of Aberdeen, although for many years contrary opinions were advocated by such eminent observers as Murchison, Harkness, Sedgwick, Arch. Geikie, and others. The paper was illustrated by a number of coloured rock-sections and views, lent for the occasion by Dr. Heddle, of St. Andrews, *Hon. Member*. The subsequent discussion was taken part in by Mr. John Young, F.G.S., Mr. M. Blair, Mr. David Forsyth, and other members. Mr. Jolly, in replying, gave some particulars regarding the proposed long excursion during the last week of July to Loch Maree, for the purpose of studying on the spot the disputed succession of the N.-W. Highland rocks.

Society's Rooms, 207 Bath Street,

27th May, 1886.

Mr. William Jolly, F.G.S., *Vice-President*, in the Chair.

Mr. H. S. Hewett, 8 Milton Terrace, Langside, and Mr. John Manford, Wellfield, Partickhill, were elected Ordinary Members of the Society.

Mr. Murdoch (Hon. Secretary) gave some further particulars regarding the joint excursion with the members of the Edinburgh Geological Society to Torbanehill and Bathgate on Saturday, 12th July; and also some details as to the long excursion to Loch Maree during the last week of the same month.

Mr. D. C. Glen, F.G.S., and Mr. Murdoch, Hon. Secretary, were

appointed delegates to represent the Society at the Meeting of the British Association in Birmingham in September next.

Several photographic groups of members, taken at the recent excursion to Glenfiler, were exhibited, and names of those who wished to obtain copies were requested to be sent to the Hon. Secretary.

Dr. J. R. S. Hunter, F.R.Ph.S.E., *Hon. Member*, read a paper entitled "The Geology of Annandale." The author confined his remarks entirely to the Permian and Carboniferous rocks, illustrating them by a considerable suite of the characteristic fossils of the district spoken of. The following discussion was taken part in by Mr. David Forsyth, M.A., Mr. Dugald Bell, and Mr. John Young, F.G.S., *V.P.*, the latter remarking that all the evidence went to uphold the theory that the Carboniferous limestone strata of Annandale lie far down in the Calciferous series.

The Chairman (Mr. Jolly) then declared the 28th session of the Society to be closed, and expressed a hope that all the members would be spared to meet again in health and spirits in the following October to begin the work of a new session, bringing with them an accumulation of observations from their summer rambles.

RECORD OF THE EXCURSION

To the Parallel Roads of Lochaber in July, 1885.

Our excursion, which had been long spoken of, to visit the celebrated Parallel Roads of Glen Roy, was successfully undertaken during the last week of July, 1885, by a joint party of the members of the Edinburgh and Glasgow Societies. Those gentlemen present were—Dr. Stevenson Macadam, Dr. Semple, Messrs. James Melvin, Ferguson, R. Matheson, and the Rev. Mr. Kennedy, of the Edinburgh Society; while representing this Society were—Messrs. William Jolly, David Tullis, James T. Tullis, Renwick, Horne, W. Stewart, J. B. Murdoch, and Dr. Gilmour. The party was also joined by Mr. Boyd, H.M. Inspector of Schools, Mr. T. C. Maggs, F.G.S., and Mr. Livingston, Fort-William.

Of the famous "Roads" no account need here be given, as a summary of all that has been written and said about them will be found in Mr. Jolly's paper at page 40 *antea*.

Favoured by the most glorious weather, the Glasgow party left Buchanan Street Station for Oban on Monday morning, being joined in the afternoon by the Edinburgh contingent.

At Fort-William a sudden resolution to ascend Ben Nevis was come to, and almost the whole party made the ascent, remaining in the Observatory on the top all night. The sunrise on Tuesday morning alone rewarded all their toils. With a clear and brilliant sky in all directions but the south, where a massive rain-cloud canopied all below, and resembled on its upward surface, with here and there a mountain-peak appearing through it, an ancient palaeocrystic sea, the panoramic view was superb

beyond description. Hill upon hill, loch upon loch, were seen to the fullest possible extent, including those of Rum, Muck, Eigg, Skye, Harris, Uist, the Moray Firth, with Ben Lawers and Schiehallion. By nine o'clock the descent was accomplished, and all were *en route* for Roy Bridge Hotel where the head-quarters of the party were. After breakfast Glen Roy was visited, and the "Roads" were minutely inspected. Wednesday was devoted to an examination of the widely-extended moraine of Roughburn, and the wonderful glaciation at the mouth of Loch Treig, with the terminal horse-shoe moraine in Glen Spean. On Thursday Coire-an-Eoin deer-forest was visited, and here again the evidences of glaciation were intense. On Friday another visit was paid to Glen Roy and Glen Colleraig, and some points bearing more particularly on statements made by Mr. Milne Home were carefully noted and recorded. On Saturday the party left with regret its pleasant surroundings, and after a long and super-heated journey, *via* Oban, reached in safety the point from which they had started on the previous Monday.

Mr. William Jolly, F.G.S., who had undertaken the conductorship of the party, proved himself to be thoroughly master of the district, and was a most admirable "guide, philosopher, and friend." Indeed, the entire success of the expedition was in great measure owing to his excellent arrangements, and before the party broke up a special vote of thanks was awarded by acclamation to him.

Many of those who were present had not previously been known to each other, but there existed throughout the utmost harmony and good fellowship, and one and all expressed a hope that the Glen Roy excursion might prove to be only the forerunner of a long series of similarly successful excursions to the more notable geological localities in Scotland. M.

Abstract of the Treasurer's Accounts for the Year ending 30th September, 1884.

CASH ACCOUNT.

RECEIPTS.

Balance—Due by the Treasurer at close of last Account,		£1	18 11
Annual Subscriptions—			
Arrears for 1881 and 1882-83, - -	£2 10 0		
For current year, 150 at 10s., - -	75 0 0		
New Members, 15 at 10s., - - -	7 10 0		
		85	0 0
Life Membership Subscription—Mr. C. L. Dobbie, -		5	5 0
Interest—On Invested Funds, - - - - -		9	15 10
Publications Sold, - - - - - - -		7	2 3
Bank Account—Drawn, - - - - - -		56	0 0
		£165	2 0

EXPENDITURE.

Transactions—			
Printing Part I. of Volume VII., -	£67 12 0		
Binding do., - - - - - -	5 1 0		
Lithographing and Engraving, -	19 2 6		
		£91	15 6
Ordinary Expenditure—			
Printing Cards and Circulars, - -	£28 11 6		
Minute and Receipt Books, - -	1 8 6		
Rent, Insurance, and Attendance, -	13 1 6		
Collector's Commission, Postages, and Petty Expenses, - - - -	4 8 6		
Carriage of Parcels, - - - -	3 13 10		
Disbursements by Secretaries, - -	7 4 0		
Subscription to Palæontographical Society, - - - - - -	1 1 0		
		59	8 10
Bank Account—Lodged, - - - - - -		12	0 0
Balance—Due by the Treasurer, - - - - -		1	17 8
		£165	2 0

ABSTRACT OF TREASURER'S ACCOUNTS.—*Continued.*

STOCK ACCOUNT.

To Balance to Credit,			£523	17	8		
NOTE.—The Expense of Part II., Vol. VII. of *Transactions*, forms a deduction from this sum.							
			£523	17	8		
By Funds Invested—							
Loan to Corporation of Campbeltown,	£250	0	0				
Cash in Bank on Deposit Receipt,	12	0	0				
						£262	0	0
,, Cash in Treasurer's hands,						1	17	8
,, Books in the Library,						150	0	0
,, *Transactions* in Stock,						50	0	0
,, Furniture,						22	0	0
,, Fossils,						18	0	0
,, Microscope,						20	0	0
						£523	17	8

LIFE SUBSCRIPTION ACCOUNT.

1884—Sept. 30.—To Balance to Credit,			£120	15	0		
			£120	15	0		
1883—Oct. 1.—By Balance,						£115	10	0
Nov. 10.— ,, Mr. C. L. Dobbie,						5	5	0
						£120	15	0

Abstract of the Treasurer's Accounts for the Year ending 30th September, 1885.

CASH ACCOUNT.

RECEIPTS.

Balance—Due by the Treasurer at close of last Account,		£1	17 8
Annual Subscriptions—			
Arrears for 1883-84,	£2 10 0		
Subscriptions for current year, 153 at 10s.,	76 10 0		
Do., New Members, 15 at 10s.,	7 10 0		
		86	10 0
Interest on Invested Funds,		10	0 5
Publications Sold,		2	18 0
Bank Account—Drawn,		12	0 0
		£113	6 1

EXPENDITURE.

Transactions—			
Lithographing Plates for Part II., Volume VII.,		£17	12 0
Ordinary Expenditure—			
Rent, Insurance, and Attendance,	£13 9 0		
Bookbinding,	9 8 8		
Distributing *Transactions*, etc.,	3 18 6		
Carriage of Parcels,	1 6 5		
Printing Cards, Circulars, and Receipt Book,	5 3 6		
Disbursements by Secretaries,	4 11 6		
Do. by Librarian,	0 7 4		
Collector's Commission, Postages, and Petty Expenses,	4 10 9		
Subscription to Palæontographical Society,	1 1 0		
		43	16 8
Library, for New Books,		10	0 0
Bank Account—Lodged,		40	0 0
Balance—Due by Treasurer,		1	17 5
		£113	6 1

ABSTRACT OF TREASURER'S ACCOUNTS.—*Continued.*

STOCK ACCOUNT.

To Printer's Account for Part II., Vol. VII., of *Transactions*,					£74	14 0
,, Sundry Petty Debts,					12	0 0
,, Balance to Credit,					475	3 5
					£561	17 5

By Funds Invested—						
Loan to Corporation of Campbeltown,			£250	0 0		
Cash in Bank on Deposit Receipt,			40	0 0		
					£290	0 0
,, Cash in Treasurer's hands,					1	17 5
,, Books in the Library,					160	0 0
,, *Transactions* in Stock,					50	0 0
,, Furniture,					22	0 0
,, Fossils,					18	0 0
,, Microscope,					20	0 0
					£561	17 5

LIFE SUBSCRIPTION ACCOUNT.

1885—Sept. 30.—To Balance to Credit,					£120	15 0
1884—Oct. 1.—By Balance,					£120	15 0

OFFICE-BEARERS.

SESSION 1885-86.

President—Sir WILLIAM THOMSON, LL.D., F.R.S., &c.

Vice-Presidents.

Mr. WILLIAM JOLLY, F.G.S. Mr. D. C. GLEN, F.G.S.
Mr. JOHN YOUNG, F.G.S.

Council.

Mr. D. Forsyth, M.A., B.Sc.	Mr. John M. Campbell.
Mr. Joseph Sommerville.	Mr. James Anderson.
Mr. Charles L. Dobbie.	Mr. Archibald Robertson.
Mr. John Farquhar.	Mr. Daniel M'Millan.
Mr. Dugald Bell.	Mr. James Dairon, F.G.S.
Mr. William Armour.	Mr. Matthew Blair.

Hon. Treasurer—Mr. John Wight, C.A., 150 Hope Street.

Hon. Librarian—Mr. James White, 56 Rose Street, Garnethill.

Hon. Secretary and Editor of *Transactions*—Mr. James B. Murdoch, Barclay, Langside.

Assistant Hon. Secretary—Mr. Gavin M. Pratt, 104 West Graham Street.

Publishing Committee.

Mr. John Young.	Mr. Dugald Bell.
Mr. D. C. Glen.	Mr. Gavin M. Pratt.
Mr. David Forsyth.	Mr. J. B. Murdoch (*Convener*).

Library and Museum Committee.

Mr. C. L. Dobbie.	Mr. James Anderson.
Mr. William Armour.	Mr. James Dairon.
Mr. David Forsyth.	Mr. James White (*Convener*).

Finance Committee.

Mr. Archibald Robertson.	Mr. John Farquhar.
Mr. D. M'Millan.	Mr. J. Wight (*Convener*).

Auditors.

Mr. George R. Alexander.	Mr. John Robertson.

TRANSACTIONS

OF THE

GEOLOGICAL SOCIETY OF GLASGOW.

No. XVIII.—On the Post-pliocene Beds of the Irvine Valley, Kilmaurs, and Dreghorn Districts. By Robert Craig, Langside, Beith, *Corresponding Member.*

[Read 13th January, 1887.]

Introduction.—On 12th January, 1882, Mr. John Young, F.G.S., and the writer, exhibited before this Society a fragment of a tusk of *Elephas primigenius*, Blum., and some shells, which had been found in sinking a pit on the farm of Drummuir, Dreghorn. These remains had been brought to our notice by Mr. Thomas Shore, at that time a clerk in the employment of Messrs. Merry & Cuninghame, the owners of the pit. In answer to a query, he stated that the shells, and "piece of wood," for which the tusk was at first mistaken, had been found in a bed of sand resting upon Carboniferous strata, and below 80 feet of Boulder-clay; but as regards the statement that the shell bed rested upon Carboniferous strata, this was afterwards discovered to be incorrect.

This find was an important one, Drummuir being nearly three miles south-west of the old quarry at Greenhill, where so many tusks of the Mammoth were discovered about sixty years ago, and I at once began to make further investigations. On proceeding to the place, I found that the discovery had been made in No. 5 pit, Drummuir, Warwickhill Colliery, belonging to the Glengarnock Iron Company, and I received from Mr. John Cuninghame, one of the partners, not only full permission to examine the pit, but also kind assistance by the loan of surface sections of numerous bores, which had been put down between Kilmarnock and Irvine,

for comparison with pit sections put down in the same district. The manager, the late Mr. Walker, also gave me every facility and help in carrying out my investigations.

Section of the Pit No. 5, Drummuir.—The following section gives, in descending order, the beds cut through before the Carboniferous strata were reached :—

1st. Boulder-clay, 76 feet.
2nd. Stratified Sand and Clay, 2 feet.
3rd. Sand, about 4 feet, the Mammoth and Shell bed.
4th. Sands and Gravels, 20 feet.

The first of these beds is the Boulder-clay of the district, a hard stony clay, impervious to water, and of a light-brown colour, with a small percentage of carried rocks.

The second, Stratified Sand and Clay, is a series of very fine laminations of alternate layers of sand and clay, connected with the Boulder-clay. The clay layers at the bottom of this bed are of fine mud from $\frac{1}{16}$ to $\frac{1}{8}$ inch thick, the sand being 1 inch thick ; but this rapidly changes, the layers of clay getting thicker, and the sand thinner, so that in the height of 2 feet the sand has fallen into very thin laminæ, while the clay layers have thickened, imperceptibly running into Boulder-clay of the same character as that overlying this bed. This is no new feature in this district. The pit-sinker, Mr. Love, informed me that he had found this laminated sand and coarse clay, in a bed 6 feet thick in the bottom of the Boulder-clay ; and another sinker, Thomas Crawford, who has put down a number of the pits in this district, fully corroborated Love's statement. These stratified beds are not always present, but they have been found in a few of the pits. I found fragments of broken shells as high as the 2 feet, and I picked out a whole valve of *Astarte sulcata*, Da Costa, of large size, in sand about the middle of the bed.

The third bed of the section is the fossiliferous one, about 4 feet in thickness, though, as no sharp line divides it from the sand below, this depth is assumed, but shells are found throughout the whole 4 feet, if not some inches deeper. About a foot on the top is fuller of mud than it is below this line, and in the bottom of this muddy sand the Mammoth tusk was found.

The Sands and Gravels, the fourth bed of the section, form a series of unfossiliferous beds, 20 feet thick, and hold from top to bottom a small percentage of, apparently, West Highland rocks.

The Mammoth and Shell Bed.—In sinking through the fossiliferous sand (the 3rd of the pit section) the sinkers came upon the tusk, lying diagonally across the shaft on a horizon agreeing with the bedding of the sand, but, mistaking it for a piece of fossil wood, they broke it up, and but for the curiosity of a joiner and another individual, it would never have been further heard of. One of the fragments, which came into my hands through the clerk, Mr. Thomas Shore, I sent to my friend, Mr. John Young, who at once discovered its value, and it was secured for the Hunterian Museum, along with some of the shells found with it. I was informed by Mr. Love, the pit-sinker who found it, that the total length of the tusk was about 5 feet, and its greatest diameter about 6 inches. He said that about 2 feet of the root or base end was in a state of decay, and fell into dust on being lifted. This was found to be correct, from the large quantity of dentine fibre discovered by washing parcels of the sand in which the tusk had been embedded.

This washing and examination of the sand was done by Mr. David Robertson, F.G.S., to whose kindness I am indebted for the list of fossils from No. 5 pit, Drummuir, given in the list appended to this paper. In the different parcels of sand sent to him Mr. Robertson found eight genera and ten species of Mollusca; twenty genera and thirty species of Foraminifera; and five genera and seven species of Ostracoda. There were also found by him fish scales, the elytra of a beetle, and the seeds of a plant. In two parcels taken from the group of Sands and Gravels, Mr. Robertson found five genera and eight species of Foraminifera, and a fragment of an Ostracod; but, as they are identical with those found in the fossiliferous bed, and as the sand was taken from the pit mouth shortly after a severe storm of wind, there is a probability that they may have been blown from the sand of the fossiliferous bed, which was lying close to the pit mouth, on to the end of the heap which had come from the Sands and Gravels. As, with this doubtful exception, this group of beds, the 4th of the No. 5 pit section, is unfossiliferous, I have not placed the shells found in it in the list.

The Mammoth and Shell bed, the 3rd of this section, differs from the section of No. 9 pit, Woodhill, as given by Mr. Young and the author in a paper read before this Society on 1st April, 1869, and printed in the *Transactions*, vol. iii., p. 310; and it also

differs from the section of the stratified beds, or bed, beneath the Boulder-clay in the old quarry at Greenhill, described by Dr. James Bryce in a paper read before the Geological Society of London on 25th January, 1866, and published in the *Quarterly Journal*, vol. xxi., p. 213. In his section, Dr. Bryce makes an arbitrary division of the deposits found here beneath the Boulder-clay into three beds of distinct character, as follows :—

No. 2. Hard gravel; thickness, 2 feet; this rests on the Carboniferous strata.

„ 3. Fine blue clay, Mammoth bed; thickness, 9 inches.

„ 4. Sand, 6 to 18 inches.

The section given by Mr. Young and myself of No. 9 pit, Woodhill, already referred to, is almost exactly the same as that given by Dr. Bryce. It was furnished by Mr. Yates, jun., and was published by us in all confidence at the time. However, when the pit was worked out, and while filling it up, Mr. Yates, in accordance with a request which I made to him for further examination of the fossiliferous bed, took out the boarding from the shaft opposite this bed, and found it to be different from the published section. Unfortunately, after a few buckets-full of the sand had been removed, the side of the pit slipped in, stopping further examination, but enough was seen to prove that there was no intercalated "peaty bed," and that the sand was fossiliferous from top to bottom. The only thing approaching peaty matter was that the sand was darker in colour, and was muddier on the top of the bed as it neared the Boulder-clay. Thus, the section of No. 9 pit, Woodhill, proved to be very similar in character to the one in an air shaft, distant from it to the south-east 150 yards (not 250, as in our paper, by an overlooked typographical error).

Recent occurrences have also thrown doubts upon the arbitrary division of the Mammoth bed in the Greenhill old quarry into three beds of distinct character, as given by Dr. Bryce in his section. It appears that he had only one object in view in opening up the old quarry, which at that time had been closed for about twenty years, and that was to verify whether the tusks were found in true Boulder-clay, or in a bed of stratified clay. Roxbrough, the lessee of the new quarry there, had worked in the old quarry, and was the "aged quarryman" who, Dr. Bryce said, gave him the section, which agreed with the one furnished him by Mr. Turner, the Duke of Portland's factor. Roxbrough was also employed to

re-open a pit in the old quarry, and it is strange that Dr. Bryce did not take a measurement of the re-opened section. That he did not he admitted in his paper to the Geological Society, according to the report in the *Geological Magazine*, vol. ii., p. 127, which says that "Dr. Bryce stated that the section had been sent by Mr. Turner." Mr. Turner, who is still living, corroborates this; and Roxbrough always said that Dr. Bryce did not take the section, as part of it had slipped in before he arrived. Yet Dr. Bryce speaks of having examined the sand bed, and that he found it thinned out eastward and westward. Roxbrough, no doubt, gave the section with the three distinct beds, and believed that he gave them correctly, although his memory was being influenced by the remembrance of conversations that he had heard. He was not in the quarry when any of the tusks were found, but he had heard from men who visited the quarry that the Mammoth was a land animal, and would be found on old land. This idea had got hold of all the quarrymen, pitsinkers, and others in the district, and the consequence was the invention of a "peaty bed" below the shell bed, in which the Mammoth remains were found.

The late discovery by Mr. Bennie, of the Geological Survey, of two bits of clay from the Elephant bed, Kilmaurs, is of high value. They had been sent to the Wernerian Society, along with part of a tusk, by Mr. Alexander Hood, surgeon, Kilmarnock, in 1817; and had been taken that year from the clay in the Greenhill quarry, in which the tusks were discovered. They had been properly labelled. They had been laid aside for nearly fifty years, when, fortunately, Mr. Bennie came across them with their labels entire, and examined them by washing. The result was given by him in a paper read before the Royal Physical Society of Edinburgh, on 20th of May, 1885, which was published in the *Proceedings* of the Society for that year, p. 451. From this paper I extract this and the following remarks which refer to it. In the examination of one of the pieces Mr. Bennie found one valve of *Astarte compressa* and a few valves of *Leda pygmæa*, with eight genera and nine species of Foraminifera, and five genera and ten species of Ostracoda. A number of seeds of plants and fragments of beetles were found in the other piece of clay, but no marine organisms were reported. This discovery is of great value, not only throwing light upon this celebrated bed, but in re-directing the attention of geologists to the report of the late Mr. Johnston of Redburn that

marine shells were found in the clay in which the tusks were discovered, which had been lost sight of in consequence of the publication of Dr. Bryce's section.

Mr. Bald, in bringing the discovery of Mammoth tusks before the Wernerian Society (see *Memoirs*, vol. iv., p. 64), and apparently quoting from Mr. Johnston's report, states that the tusks were found in a clay of light brown colour, which had changed into a dark brown around the remains, with an offensive smell. "The tusks were found lying in a horizontal position with several small bones near them, and it is particularly to be remarked that several marine shells were found among the dark-coloured earth."

Mr. Bennie's discovery, coming as contributory evidence in support of Mr. Johnston's important remark, destroyed Dr. Bryce's arbitrary division of the stratified material beneath the Boulder-clay in the Greenhill old quarry into three beds of distinct character. This, when taken with the other sections of the bed, is sufficient to prove that marine shells are not confined to the sand said to rest upon the Mammoth clay bed, but that they also are found in this so-called clay bed itself. And if ever an opportunity presents itself for the examination of this section, I have not a doubt that shells will also be found in the run gravel below the clay, as was the case in No. 9 pit, Woodhill, as now ascertained.

In summing up the evidence, I have arrived at the following conclusions regarding the fossiliferous bed:—The shell bed in the two pits on Woodhill, and the Mammoth and Shell bed in the old quarry at Greenhill, and in No. 5 pit, Drummuir, are all parts of the same bed. There is a distinctively uniform character running through them that cannot be overlooked. Remains of a land fauna and flora, carried in by mechanical means, have been deposited in this bed of otherwise true marine character, and reached their greatest extent when the bed was about two-thirds deposited, in which position the Mammoth remains and the largest amount of plant remains were found. Marine shells, etc., being found mixed up with these prove that no cessation in the deposition of this marine bed had taken place. After this time an increased inflow of land organisms and an increase of mud have taken place, and have continued, until the bed was finally brought to a close by the advance of land ice and the deposition of the Boulder-clay.

This bed has been certainly found in four pits, and is reported

to have been found in another (doubtfully) besides the old quarry on Greenhill. The fourth pit was No. 1, Finnie's Colliery, on the side of the Carmel, half a mile or so below Crosshouse ; and the other, which I regard as doubtful, was near (but a little to the north-west of) Crosshouse. Having been only found in these few places amidst a great many pits sunk around, it is evident that these are only patches of the bed preserved in hollows of the underlying sands and gravels.

Mr. Bennie, in his paper mentioned above, states that plant remains were only found in one of the pieces of clay, and, referring to the marine fossils found in the other, says "the one speaks of the sea and the other of the land." But this is rather obscure, as it is not plain whether he is speaking of this clay being from an old land surface, or only of the fossils coming from the land. Whatever the meaning, there is no evidence that any surface of old land exists either in this bed or in any of the sand and gravel beds lying beneath the Boulder-clay. Still, the presence of a land, or fresh-water, flora, and the remains of land animals, show that land was at no great distance.

Age and Position.—It is a curious fact that up to the publication of Dr. Bryce's paper geologists wrote as if the tusks of the Mammoth discovered at Greenhill were all found in the Boulder-clay, or Till. Mr. Bald, among the first to notice the discovery, thought that they were found in recent deposits above the Till. Dr. Scoular, who visited the quarry, and picked half a molar of the Mammoth from the removed clay, but neither perceived sand nor shells, stated that the material in which the tusks and half molar were found was the true Till, or Boulder-clay. This statement was accepted by geologists until Dr. Bryce, who had come to doubt its correctness, applied in 1864 to Mr. Turner, factor for the estate, to re-open a section of the old quarry, in which the tusks had been found, and so prove the correctness of Dr. Scoular's statement. This was accordingly done, but beyond satisfying himself that there was stratified material below the Boulder-clay, in which old quarrymen said the tusks were found, his work threw no new light upon the question. Finding that the tusks were found in strata beneath the Boulder-clay, Dr. Bryce put down the bed as the equivalent of the Cromer Forest-bed of Norfolk, and consequently pre-glacial. Mr. Young and myself, in the paper already quoted, after a close

examination of the district and position of the beds in relation to the glacial clay, concluded that the Mammoth and Shell bed was pre-glacial. In 1872 the officers of the Geological Survey published an Explanatory *Memoir* to sheet 22 of the Survey, and in noticing the discoveries at Greenhill, state this bed to be inter-glacial. Dr. James Geikie, in his "Great Ice Age," accepts this view, and puts the bed down as inter-glacial; while in the already quoted paper by Mr. James Bennie he not only strongly upholds the same theory, but advocates its extension.

It may be difficult to find a term satisfactory for all parties, but after weighing all the available evidence, and reviewing the conclusions of the inter-glacialists regarding this bed, at least, the theory may be dismissed with the Scotch verdict of "not proven." If the inter-glacial position of this bed be founded upon the evidence given in the Survey *Memoir* already quoted, as it appears to be, then the evidence is defective. The *Memoir*, after noticing that some observers had compared the horizon of the bed to the well-known Forest bed of Cromer in Norfolk, says, "There are, however, no grounds for this inference." It continues, "An examination of the numerous bores and pit sections . . . in the Kilmaurs district shows that the Boulder-clay there contains interstratified beds of sand, gravel, and clay. Where the level of the surface of the solid rocks rises towards the surface of the ground, the intercalated strata of sand die off the slope until the rock comes to be covered directly by the overlying Boulder-clay. Where, on the other hand, the level of the rock sinks, as it does southwards and westwards, it passes beneath the horizon of the sand-beds, and a lower Boulder-clay makes its appearance under these beds. There can be no doubt that the strata containing the organic remains were formed during the deposition of the Boulder-clay which is found both beneath and above them," etc. It was, no doubt, beyond the scope of the *Memoir* to furnish details, yet, in a question of importance such as this, one or two sections might have been given where this lower Boulder-clay exists. If I understand the above rightly, the "sand, gravel, and clay" refers to the beds of sands and gravels which fill the valley of the Irvine beneath the Boulder-clay, and extend from near Shewalton to the village of Galston. Their breadth is very irregular, never more than one mile or so, with considerable gaps, and they run in depth from a mere nothing to nearly 40 feet. In no single pit that I have

known, and I have been on the outlook now for a quarter of a century at least, has anything that could be called Boulder-clay ever been found beneath them, but they have always been found resting upon the Carboniferous strata. It is true that in a very few bores, the borers have registered in their journals, as existing in these sands and gravels, intercalated beds, as "gravel with clay," "gravel and clay," and "stony clay." Wherever these bores have been proved by pit, or open, sections, no material corresponding to Boulder-clay has been found. In a bore put down close to where No. 5 pit, Drummuir, was afterwards sunk, the borer had registered three kinds of Boulder-clay intercalated by beds of gravel, and $8\frac{1}{2}$ feet of "gravel mixed with clay" beneath the sands and gravels, and resting on the Carboniferous strata. When the pit was afterwards sunk the Boulder-clay was found persistent in character throughout, and the $8\frac{1}{2}$ feet under the sands and gravels was gravel of a clean and washed appearance, with no clay whatever mixed in it. In no pit, as already stated, have I known Boulder-clay, or clay of any kind, to have been met with, either beneath these sands and gravels, or intercalated with them. They, however, differ in character in different pits; in one they may be, and this is their general character, pure sand and gravel; in another they are nearly pure sand so indurated that a shaft can be sunk 6 feet without boarding; while in a third soft loose sand mixed with mud predominates. One thing the open sections prove, that bores not attended by experts are totally valueless in the settlement of delicate geological questions.

Conclusions.—Taking all this negative evidence into consideration, with the positive evidence now available, I see no cause to change the conclusions arrived at in our joint paper of 1869. Dr. Bryce's surmise that the fossiliferous bed may be the equivalent in age of the Cromer Forest-bed is, in my opinion, not far from being correct. I would even put these sands and gravels, with the fossiliferous sand bed, as of earlier age than this Forest bed, but it is impossible to correlate the glacial deposits of Scotland with those of England for any practicable purpose. From the first inflow of ice until its final disappearance deposition and destruction must have been at work. While deposition was active in one locality destruction would be as active in another where there was not water of sufficient depth to act as a preservative. Still there is a general character between these beds of the Irvine valley, and the

beds in the Bure valley, near Norfolk. Both form a series of beds of sands and gravels, capped with a fossiliferous sand bed holding marine fossils. Both underlie the great mass of glacial deposits in their respective localities; and the shell *Tellina balthica*, Linn., makes its first appearance in English strata in the Bure valley beds, and its first appearance in Scottish strata in the Irvine valley. As this shell is found in all the higher fossiliferous glacial clays, and is still living in British waters, its presence is no proof of the age of this bed; still the coincidence is remarkable when the inferior position of both beds to the Boulder-clay of their respective localities is considered.

In thus putting this series of Sands and Gravels, with the Mammoth and Shell bed, at the very base of the glacial deposits, I admit that it supposes a submergence at the commencement of the glacial period, a subsidence not recognized by any Scottish geologist, so far as I remember. But the stratified layers of alternate sand and clay at the bottom of the Boulder-clay in the Drummuir pit is evidence of deep water, otherwise these laminated strata would have been destroyed by the ice that deposited the 76 feet bed of clay and stones which overlies them. The greater number of the Foraminifera found in the fossiliferous bed are still living, according to Mr. H. B. Brady, off the Shetland Islands, and to the north of them, in water of from 75 to 90 fathoms. A few are of brackish water habitat, but these might have been flooded in, as in all probability the tusks and land plants were. The increase of mud in the sand above the line of horizon on which the tusk was found in No. 5 pit, Drummuir, may indicate the approach of the ice. As it advanced, driving the land animals before it, many of them might be caught in a *cul-de-sac*, and perish of hunger, which would thus account for so many of their remains being found here.

It has been supposed by those who hold this bed to be interglacial that the group of Sands and Gravels beneath the fossiliferous bed is a re-wash from a lower Boulder-clay. But if this be so, where are the beds of fine clay which would be associated with the sands and gravels, and which are always so found in the re-washes that lie above the Boulder-clay? Their absence is a deathblow to the supposition; and as for the carried rocks, they may owe their present position to the carrying power of weeds attached to them, a power quite sufficient to account for the presence of the largest of them that I have yet seen.

Note.—On 3rd March, 1872, I read a paper before this Society, "On the Glacial Deposits of North Ayrshire," etc., which was published in the *Transactions*, vol. iv., p. 138. It may be thought that the present paper is a recantation of the opinions I then advocated, but that is not so, and I still adhere to the general views set forth in that paper. But I wish to correct one error which I then committed in putting the Kilmaurs Mammoth bed on the top of the deposits of the lower glaciation, instead of placing it at the bottom of them, as I now do. When I placed the Mammoth bed at Greenhill between the two glaciations I was working on defective evidence, and had accepted this bed as a patch of the old land which I had found in the Beith district. The correction of that evidence by the re-examination of No. 9 pit, Woodhill, the new section in No. 5 pit, Drummuir, and the finding of marine fossils in what was supposed to be the land surface in the Greenhill quarry, all go to prove that the bed is marine, and that it lies at the bottom of the glacial deposits, or rather in the earlier stages of the glacial period. With this explanation I have now no farther alteration to make on my former paper, which, like all geological papers, must stand or fall by the evidence that may turn up hereafter.

On the following pages will be found a list of organisms from the Fossiliferous Bed beneath the Boulder-clay, referred to in this paper.

LIST OF ORGANISMS FROM THE FOSSILIFEROUS BED BENEATH THE BOULDER-CLAY IN THE KILMAURS AND DREGHORN DISTRICT.

	Old Quarry, Greenhill.	No. 9 Pit, Woodhill.	Air Pit, Woodhill.	No. 5 Pit, Drummuir.
MAMMALIA.				
Elephas primigenius, Blum. (tusks).	x			x
Cervus tarandus, Linn. (horns).	x			
MOLLUSCA.				
CONCHIFERA.				
Cyprina Islandica, Linn.		x		x
Leda oblonga (*L. pernula*), Müller.		x		
,, *pygmæa*, Munst.	x		x	
Pecten Islandicus, Linn.		x		
Nucula tenuis, Mont.				x
Astarte compressa, Mont.	x	x	x	x
,, *sulcata*, Da Costa.		x		x
Tellina calcaria, Chemn.		x		
,, *balthica*, Linn.				x
Mya truncata, Linn.				x
GASTEROPODA.				
Littorina littorea, Linn.		x		x
Turritella terebra, Linn.				x
Natica Grœnlandica, Beck.		x		
,, *affinis*, Gmel.		x		
Fusus, sp. (?)				x
FORAMINIFERA (IMPERFORATA).				
MILIOLIDA.				
Biloculina elongata, D'Orb.				x
Miliolina seminulum, Linn.	x			
FORAMINIFERA (PERFORATA).				
LAGENIDA.				
Lagena globosa, Mont.				x

	Old Quarry, Greenhill.	No. 9 Pit, Woodhill.	Air Pit, Woodhill.	No. 5 Pit, Drummuir.
LAGENIDA—*Continued.*				
Lagena marginata, W. and J.			x	x
,, *melo*, D'Orb.				x
,, *Williamsoni*, Alcock.			x	x
,, *sulcata*, W. and J.			x	x
,, ,, *var. lineata*, Will.				x
Glandulina lævigata, D'Orb.	x			x
Polymorphina lactea, D'Orb.	x			
,, *myristiformis*, Will.				x
,, sp. (?)				x
Uvigerina angulosa, Will.				x
GLOBIGERINIDA.				
Textularia sagittula, De Franc.				x
Bulimina aculeata, D'Orb.				x
,, *marginata*, D'Orb.				x
,, *pupoides*, D'Orb.				x
Cassidulina crassa, D'Orb.	x			x
Planorbulina Ungeriana, D'Orb.				x
Truncatulina lobatula, Walker.	x			
Rotalia Beccarii, Linn.	x			x
NUMMULINIDA.				
Nonionina depressula, W. and J.				x
,, *asterizans*, F. and J.				x
,, *orbicularis*, Brady.	x			
,, *scapha*, F. and M.	x			
Polystomella crispa, Linn.				x
,, *striato-punctata*, F. and M.	x		x	x
,, sp. (?)				x
CRUSTACEA.				
OSTRACODA.				
Cythere Dunelmensis, Norman.	x			
,, *concinna*, Jones.	x		x	
,, *limicola*, Norman.	x			x
,, *pellucida*, Baird.				x
,, *viridis*, Müller.	x			x
Cytheridea papillosa, Bosq. (young specimen).	x			x
,, *punctillata*, Brady.	x		x	x
,, *Sorbyana*, Jones.	x			

	Old Quarry, Greenhill.	No. 9 Pit, Woodhill.	Air Pit, Woodhill.	No. 5 Pit, Drummuir.
OSTRACODA—*Continued.*				
Cytheropteron latissimum, Norman.	x			
Cytherura cellulosa, Norman.				x
Eucythere argus, Sars.				x
CIRRIPEDIA.				
Balanus porcatus, Da Costa.				x
PISCES.				
Fish scales (undetermined).				x
PLANTÆ (SEEDS).				
Potamogeton (allied to *P. rufescens*, Schard).	x		x	x
,, (allied to *P. Zizii*).	x			
,, (allied to *P. heterophyllus*).	x			
Ranunculus aquatilis.	x		x	
Myriophyllum spicatum, Linn.	x			
Carex, sp. (?)	x			
Potentilla, sp. (?)	x			
Chara, sp. (?)	x			
Isoëtes, sp. (?)	x			
INSECTA.				
Beetles (fragments).	x			x

NOTE.—I have much pleasure in stating that this list has been made up by the help of kind friends, whom I have to thank for their valuable aid. The entries in the first column, under Old Quarry, Greenhill, are taken, with Mr. Bennie's consent, from his paper, "On Two Bits of Clay from the Elephant Bed, Kilmaurs." (*Proc. Royal Phys. Soc.*, Edin., vol. viii. p. 451.) Those in the other three columns are the work of Mr. David Robertson, F.G.S., who kindly washed parcels of the sand from the pits, in which he discovered all the Microzoa, and the most of the shells recovered. The existence of seeds in the peaty clay was first demonstrated by Mr. John Young, F.G.S., who in 1869 washed a piece of clay which had been sent with the tusk of 1829 to the Hunterian Museum, finding in it "upwards of 300 seed-cases and seeds of plants, the most abundant being a species of *Potamogeton*, and one of *Ranunculus*, along with a few seeds of *Hippuris*." (See *Trans. Geol. Soc. of Glasgow*, iii., 314.) Mr. Bennie having, in 1884, recovered a bit of the peaty clay sent to Edinburgh with the tusk of 1817, followed Mr. Young's example and washed it, finding the seeds indicated in the first column of the text. (*Proc. Royal Phys. Soc.* Edin., viii., 451.)

Chris. Meadows, Delt. Robertson Brothers, Collotype.

FOSSIL TREES, VICTORIA PARK, WHITEINCH.

No. XIX.—Notes on a Section of Carboniferous Strata, containing Erect Stems of Fossil Trees and Beds of Intrusive Dolerite, in the old Whinstone Quarry, Victoria Park, Lower Balshagray, near Whiteinch and Partick. By John Young, F.G.S., and D. Corse Glen, F.G.S. With an Illustration. [Plate IV.]

[Read 12th April, 1888.]

On the north side of the Dumbarton Road, near Whiteinch and Partick, there is to be seen in the Lower Balshagray grounds a small ridge or knoll running east and west, crowned by a group of stately trees rising above the level tract of land, which here to the north bounds the river Clyde, its height above the present sea-level varying from 20 to 25 feet. The ridge is composed in its upper part of beds of intrusive dolerite, which are here seen to be intercalated with Carboniferous sandstones and shales, the igneous rock being traceable westwards for nearly two miles, when it again disappears under the overlying strata of the district. The knoll now lies within the area of ground rented by the burghs of Partick and Whiteinch as a public park, and is at its south-western extremity. In former years, a quarry had been opened in the upper bed of dolerite, the rock being used for macadamizing purposes on the neighbouring roads. Since it came into the hands of the Partick and Whiteinch Commissioners, a great deal of work has been expended in dressing up and planting the rocky slopes of the old quarry; and while employed last winter in cutting a road along the hollow of the quarry, the workmen exposed the strata in which a number of fossil trees were found to be embedded. These strata underlie the upper bed of dolerite now largely quarried away, and consist of gray sandy shales, flaggy sandstones, and dark carbonaceous shales, in the bottom of which the erect stems of the fossil trees are seen to be rooted. When the workmen came upon the upper end of the stems, the excavation was carefully continued downwards until both trunks and roots of five large trees were laid bare. Four of these stand close to each other, the fifth and largest being some distance apart at the western end of the excavation. It is very probable that other tree stems exist in the immediate proximity, as the sandstones and shales are found to be continuous on either side of the cutting for the roadway, those on the north

side being seen to extend under the overlying dolerite which has here not been quarried away. Other five trees have recently been exposed standing near the others, besides two prostrate stems, which are seen lying across the section in the cutting.

The geological horizon of the group of strata in which these trees are found lies in the middle and lower divisions of the Possil coal and ironstone series, and which extends from this point eastward under the city boundaries, where it underlies the Millstone Grit and Upper Coal Measures, the beds in question being some 500 fathoms under the upper red sandstone which lies over the higher beds of the Lanarkshire coalfield.

The occurrence of erect stems of fossil trees, apparently on the same geological horizon as those above mentioned in the old quarry at Victoria Park, has been formerly recorded from several localities to the north-west of Glasgow. The most recent was the discovery in the Gilmourhill quarry, where six erect stems, standing close together, were exposed in the year 1868, during the working of the sandstone for the new buildings of the University. The strata in which they were found were identical in character with those seen in Victoria Park quarry. As a notice of the strata of the Gilmourhill quarry, and of the erect fossil trees found there, and at other localities within this district, formed the subject of a paper read to this society by one of the authors twenty years ago (*Transactions*, vol. iii., 1869), it is unnecessary to repeat what is there stated regarding either this group of strata, its geological horizon, or its fossils, beyond the following short quotation where mention is made of the trees:—

"In the working of the upper bed of sandstone the quarrymen came upon the erect stumps of five or six large fossil trees. They appeared to be *Sigillaria*, and measured from 20 inches to 2 feet in diameter. They seem to have been broken, or to have decayed to within a few inches of the ground, and were composed of shaly sandstone, similar to the surrounding rock. The trees stood some three or four feet apart, and the roots of the one were seen in some cases interlacing with those of the others. While the remains of this old forest of the coal period were allowed to stand, they formed a very interesting object in the quarry, but they were ultimately removed in the working of the sandstone. Remains of large erect stumps of fossil trees from this neighbourhood are recorded in the

writings of Dr. Buckland, Mr. Smith of Jordanhill, and Mr. John Craig, mineral surveyor. Dr. Buckland states, in his "Anniversary Address to the Geological Society of London," 1840, "At Balgray, three miles north of Glasgow, I saw in the year 1824, as there still may be seen (1840) an unequivocal example of the stumps of several stems of large trees, standing close together in their native place in a quarry of sandstone of the Coal formation." These trees have now all been removed, but their position was, we believe, nearly on the same geological horizon as the trees found in the sandstone of the Gilmourhill quarry. It is therefore interesting to find them scattered over a considerable tract of country.

What we shall now endeavour to notice further regarding the new discovery at Victoria Park will be some of the more local conditions that the section presents and the proofs it affords of the great antiquity of the strata. There is nothing abnormal, however, in this section as to the conditions under which the trees originally existed. They evidently formed a portion of one of those widely extended coal forests, which over this district flourished on this horizon in Lower Carboniferous times. In the strata underlying and overlying the beds containing the fossil trees we have clear evidence that this region was then one of gradual and slow depression, which probably extended over the whole area of our coal-fields, and also over much of the country beyond. There is also further evidence that this general depression continued until more than 3,000 feet of strata were deposited above the particular horizon in which these trees now lie. The evidence for this assertion, as to the great accumulation of strata, and the downward movement of the beds, is revealed by the nature of the strata themselves.

It is now generally admitted by geologists that all our beds of free, or cherry coal, whether thick or thin, were derived from growths of vegetation which flourished on the tracts of land where these coal-beds now exist. On the other hand, the strata of sandstone, limestone and shale, which alternate with these coal-beds, as clearly attest in their contained fossils what were the conditions, lacustrine or marine, under which their sediments were deposited. The coal-beds mark the periods of former land-surfaces, during which the underlying crust remained stationary, whilst the sedimentary strata mark the periods of depression when the land went down under water, either of lakes or of the sea.

It may be interesting here to note the often-repeated occurrence of old land surfaces which exist, in the form of coal-beds, in the Possil group of strata lying between the horizon of the lower and upper marine limestones, near Glasgow. In the Gilmourhill quarry, already referred to, seven seams of coal were exposed in a thickness of 70 feet of strata. Mr. James Duncan of Twechar has sent us journals of bores put down through the same group of strata further to the east, in the Kelvin Valley, near Kilsyth, which show at least forty seams of coal, occupying horizons in the strata which lie under the upper, or Arden, limestone of the district; and over that, in descending series, of the Garibaldi ironstone, which is also worked in the Jordanhill and Knightswood pits, in the neighbourhood of Victoria Park, the distance, or thickness of strata, between the limestone and ironstone, being 207 fathoms, or 1,242 feet.

The seams of coal are generally thin, but several have been found of workable thickness within the district, such as the Shirva coal, which runs from 5 to 6 feet thick in the neighbourhood of Kirkintilloch and Kilsyth, and which is there worked, along with other of the thinner seams. The whole of these beds of coal indicate periods of repose, of longer or shorter duration, in which the land remained stationary, but they likewise mark as many periods of subsidence, when the land went down. When both are looked at and considered together they represent a very lengthened period of time, as the Possil group, which, it must be remembered, only forms the lower division of the 3,000 feet of coal measures formerly mentioned, once lay, we have every reason to believe, over the horizon of the trees now exposed in the quarry at Victoria Park. There is, however, a further period of time represented by the above section—the period required for the denudation of the whole of the coal measures which once lay over these beds in this district. Which of these periods was the longest, that represented by the slow growths of numerous coal seams and 3,000 feet or thereby of various intercalated sedimentary strata, or that during which the whole of this amount of strata has been removed by denudation, after the elevation of the region above the present sea-level? We are afraid that none of these points will ever be satisfactorily determined, as the period of deposition, and that of denudation, seem each so great as to lie almost beyond the grasp of the human mind.

Of the ten trees which have now been exposed at Victoria Park only the lower portion of the stems and the roots nearest to them have been preserved. One of the stems is, as already mentioned, much larger than any of the other nine, and stands apart in the western end of the excavation. It is of an oval form, and measures across the stem, which has decayed to near the level of the roots, about 4 feet by 3 feet in diameter. The other trees, which have their stems preserved to heights of from 2 to 3 feet above the roots, have diameters varying from 20 inches to nearly 3 feet, about the same size as the Gilmourhill trees. They are seen to have been buried near their roots in a dark carbonaceous shale containing numerous fragments and impressions of plant remains. A more arenaceous shale of lighter colour surrounds the upper portion of the stems. It may be here noted that the heights to which the stems have been preserved were in all probability determined by the depth of sediment which had accumulated around their bases ere the trees themselves had decayed downwards to their present level. Above this level the strata in the quarry were found to be quite continuous over the upper ends of the stems.

The erect stems of some twelve or fourteen fossil trees belonging to the lower Carboniferous Period, which were discovered by Mr. E. A. Wünsch, F.G.S., in a coast section in the Island of Arran, where they had grown on two or three distinct horizons, had the lower portion of their stems entombed in beds of volcanic ash, which determined the heights to which they were afterwards preserved. In a paper by Mr. Wünsch, with a diagrammatic sketch showing the trees in position (*Transactions*, vol. ii., p. 98), he says: "The height of the trunks is limited by the thickness—about three feet—of the enveloping bed of ash, in which they seem to have been buried suddenly. At the same time numerous branches must have been broken off, and covered up by the ash around the stems of the trees." We are inclined to believe that the preservation of erect stems of trees in any strata in which they may be found, is always due to the material having been accumulated around their bases ere the trees themselves had decayed down to the levels at which their stems are now found standing. These stems, it must be remembered, generally existed as hollow moulds which only represented the external form and the surface markings on the trees, but not

the wood itself; this having decayed in most instances ere their interiors became filled with the sandstone or shale, as the case may be, which now forms what are known as "casts" of the stems.

The external markings which exist on the casts of the stems of the trees under notice are somewhat obscure. They have been examined by Mr. Robert Kidston, F.G.S., Stirling, an authority on fossil plants whose opinion we are glad to have, and whose remarks on the subject will be found following this paper. Mr. Kidston informs us that he is inclined to regard the trees as belonging to the *Lepidodendron* family, rather than to that of *Sigillaria*. In this view he seems to be strongly supported by the abundance of fragments and impressions of stems of *Lepidodendron* which exist in the shale above the roots of the trees, and which he believes all belong to one species, *L. Veltheimianum*, Sternb., which is also found on many other horizons in the Scottish coalfield. In the shale are also found remains of stems, and various impressions of plants which have not yet been fully determined. From the way in which the intrusive dolerite is seen to have been injected among the strata in this locality, hardening, crushing, and burning the shale beds, many of the plant remains have been rendered more obscure than otherwise they might have been.

The only other traces of organic life which have yet been met with in the strata of the quarry, are the remains of Annelide burrows, which have been found in the surface layers of some of the flaggy sandstones. They belonged to a species of *Arenicola*, the tubes of which are very abundant in many of the sandstone beds lying within the Possil group of strata. For a notice of these and other organisms found in this group, we refer those interested to the list appended to the paper on the Gilmourhill quarry formerly mentioned.

The dolerite which is seen to be intrusive in the strata of the Victoria Park quarry presents the same mineralogical characters as that found intrusive in other horizons of the coal measures in the districts around Glasgow. It generally occurs in the form of extended sheets or bosses, and although seen to be intrusive in several distinct horizons of strata which range from the lower limestone series up into that of the higher coal measures, yet it is believed to have all been erupted about the same period of time, a period later, as has been clearly shown (at

pp. 39 and 44 of *Memoirs* of the Geological Survey for sheets xxiii. and xxxi.), than the deposition of the Scottish Carboniferous strata, although probably older than the upper red sandstone that overlies the coal, and in which the dolerite has apparently not yet been found to be intrusive.

In its several exposures over the country this dolerite is seen to vary more in its crystalline characters than it does in its mineral composition. It is a truly basic rock, of a dark greenish-grey colour, which within the limits of the same quarry often varies from a coarsely crystalline into a fine grained and compact structure. Where thinner sheets and veins derived from the main mass are found to be intrusive in higher or lower levels of the strata in the same locality, as in the quarry at Victoria Park, the rock is generally seen to pass from its normal dark colour into different shades of light grey and greyish-white, the alteration being evidently due to its contact with the sedimentary rock, and to rapid cooling, especially along the lines of contact. In this quarry we have the interesting evidence that along these lines, especially in the thinner veins, the dolerite has cooled as a vitreous glassy lava, in which a thin layer showing micro-spherulitic structure has been developed during the process along the surface of both faces of the vein. These veins are now seen to have lost their glassy structure through devitrification, and are of a whitish colour, but their spherulitic structure, which still remains, clearly indicates that they once existed as veins of a glassy tachylite. This is the first instance in which we have found such a structure amongst the dolerites of the Glasgow coalfield.

The exposure of the dolerite here is evidently due to a fault which has brought it nearer to the surface, it having subsequently been laid bare by denudation of the overlying strata. Near where the trees have been found it dips, at a low angle to the north-east, under the higher remaining strata of the district. About twenty years ago it was bored through at a considerable depth underground, on the farm of South Balgray, in this district, but to the north it does not again show itself at the surface until we come to the neighbourhood of Milngavie, where its intrusive sheets are once more seen, but on a much lower horizon, amongst the sandstone strata which underlie the Campsie main limestone. At the Linn of Baldernock, a little further to the east, the dolerite is seen to be intrusive amongst the same limestones, forming the

roof of one of the mines. Its subsequent intrusive character is often clearly displayed in many of the localities where it appears at the surface, as well as in those places where it has been met with in underground workings, the strata with which it comes in contact bearing evidence of having been strongly heated and otherwise altered, coal being converted into anthracite and coke, or sometimes burnt into a sooty condition, while sandstones are often much hardened and cracked, and shales are porcellanized into flinty conditions (see Geological Survey *Memoirs*). Such alterations in the strata, where these come in contact with the intrusive dolerite at Victoria Park old quarry, are clearly traceable at several places where the beds are exposed.

At one spot within the area of the excavation in which the erect stems of the trees are standing, one of the thinner horizontal veins of dolerite, in its extension through the shale, cuts right across one of the trees a little above the roots, and now forms a layer across the stem. Besides the geological interest attaching to this mode of occurrence of the dolerite, the fact also affords clear proof of its intrusion subsequent to the growth of the trees and the deposition of the shales and sandstones which afterwards surrounded them.

In the Geological Survey *Memoirs* explanatory of the several sheets which embrace the Western Scottish coal-field, and which, in the course of this paper, have been several times referred to, numerous interesting instances are given to show how these intrusive dolerites or basalts have altered and burned many of the coal strata with which they have come in contact, and also how the igneous rock itself has been altered from its normal conditions into that of the white decomposed varieties found in many districts.

In bringing our remarks on this interesting section and its fossil trees to a conclusion, we have only to add that we feel much more might be written upon the geological phenomena here displayed, as well as on the lessons which might be deduced. The nature of the strata in which the stems have been embedded forbids the idea of their being preserved for any great length of time, unless carefully protected from weather influences. Should their fate, however, be like that of the group of Gilmourhill trees, already mentioned, we shall at least have the satisfaction of recording, by the excellent and faithful drawing

made for us by our friend Mr. Chris. Meadows, their present appearance, as well as their position and relation to each other, when seen standing on the ground on which they lived and died countless ages ago.

No. XX.—Note on the Nature of the Fossil Trees found at Whiteinch. By R. Kidston, F.R.S.E., F.G.S.

[Read 12th April, 1888.]

In view of a paper being read this evening by Mr. John Young, F.G.S., and Mr. D. C. Glen, F.G.S., on the section of Carboniferous strata containing erect stems of Fossil Trees and beds of intrusive dolerite, near Whiteinch, might I be allowed to correct a popular error, which has been widely circulated in the newspapers, in regard to the generic identification of these trees.

The fossil trees and their stigmarian roots lately discovered at Whiteinch have been usually referred to as *Sigillaria*, simply, I presume, from the stems and their surrounding matrix showing irregular longitudinal fissures. Such irregular fissuring of the trunk only occurs in the clathrate *Sigillaria*, and never on those with longitudinal ribs. The ribs on *Sigillaria*, when observable at all, are always regular, and do not suddenly cease and a new one spring up a little to the side of the first, run a short distance, and in turn cease. In addition, the furrows (they cannot be called ribs) on the Whiteinch examples are slightly flexuous or zigzag.

In the beginning of March I paid a visit to the Victoria Park, Whiteinch, and through the kindness of the curator, Mr. Duncan, had every facility given me for a careful examination of the fossils. All the trunks I saw had more the character of *Lepidodendron* than of *Sigillaria*, and even did they belong to *Sigillaria* it must be to the clathrate group.*

In certain *Lepidodendra* the bark, from pressure exerted on it from within by the ever increasing stem, splits longitudinally into irregular clefts, and in two *Sigillariæ* (*S. discophora*, König, sp., and *S. Taylori*, Carr.), this also occurs from a similar cause, but in the latter genus I have not seen it carried to the same extent. From any character shown by the stems themselves, as exhibited at

* Those with contiguous leaf-scars and no ribs, as *S. Brardii*, Brong.

Whiteinch at the time of my visit, no sure generic determination could therefore be made with certainty.

There is, however, another way by which not only the genus, but also the species to which the Whiteinch fossils belong, can be ascertained, viz., by the fossils found in the shale surrounding the trunks. These, which were kindly shown to me by Mr. Duncan, comprised only two species—*Lepidodendron Veltheimianum*, Sternb., and *Stigmaria ficoides*, Sternb., sp.—the latter being in reality the root of the former. There cannot then be any doubt as to the trunks being those of *Lepidodendron Veltheimianum*, and not those of *Sigillaria*. However well such large trunks may be preserved, I suspect in almost no case would the leaf scars be preserved at the base of the stem, for in the course of nature they would become effaced by exfoliation and the natural fissuring of the bark.

There is in my collection a large number of specimens of *Lepidodendron Veltheimianum*, showing this species in different stages of growth, and two of these fissured specimens I have already described. (*Annals and Mag. Nat. Hist.*, vol. xvi., 1885, p. 166, specimens 8 and 9.)

Lepidodendron Veltheimianum is an extremely common species in the Carboniferous limestone series and the Calciferous sandstone series of Scotland.

Ribbed *Sigillariæ* are all but unknown in the Lower Carboniferous rocks of Great Britain, and, so far as I can remember, I have only seen a single specimen from rocks of this age.

No. XXI.—On the Glacial Phenomena of Scotland, with reference to the Reports of the Boulder Committee of the Royal Society of Edinburgh. By Dugald Bell.

[Read 12th May, 1887.]

The Twelfth Volume of the *Proceedings of the Royal Society of Edinburgh*, which has lately been added to our Library, contains the "Tenth and Final Report of the Boulder Committee, with Appendix containing an Abstract of the information in the nine Annual Reports of the Committee, and a Summary of the principal points apparently established by the information so received." This bears to have been presented to the Society in July, 1884. The Committee was appointed in 1871, so that their labours extended over a period of thirteen years. The publication of this final *Report*, and of the Summary which it embodies, seems to furnish a favourable opportunity for reviewing the work of the Committee as a whole, and endeavouring to estimate and sum up the results.

These *Reports*, it is scarcely necessary to say, contain a great mass of interesting information regarding boulders and their distribution in all parts of our country; information which has never before been presented in so complete and authentic a form, and which cannot be overlooked by any future student of the subject. In collecting it, the Committee have certainly rendered an important service to Geological science. Special acknowledgments are due to the Convener, Dr. Milne-Home, for the energy and enthusiasm with which he threw himself into the work. As has been said elsewhere—"At a time of life and after services which might entitle him to leave such observations to younger men, he has gone over the greater part of Scotland, visiting every remarkable boulder he could hear of, measuring, sketching it, noting its position, and otherwise putting it on record." ("Among the Rocks round Glasgow," p. 162.) We repeat this tribute all the more readily that we shall have occasion to differ widely from Dr. Milne-Home with regard to the interpretation of many of the facts recorded, and with regard to his general theory of the glaciation of our country—a difference which we hope always to express in a manner consistent with the respect due to him as a gentleman of high reputation and a veteran promoter of the science.

One does not go far in these *Reports* without discovering that

the Convener is an out-and-out advocate of the "iceberg hypothesis;" glaciers or land ice he introduces as little as possible, apparently regarding bergs or floating ice as able to account for almost everything that is required. All the phenomena under notice he thinks may have been produced by icebergs carried by ocean currents from the north-west, and drifting over the country at a time when it was submerged to a depth of about 2,000 feet beneath its present level.

This theory he seems to have been led to adopt from his observations in the eastern and south-eastern parts of Scotland. Finding that it accounted fairly well, on a general view, for the facts observed in these districts, and also that it seemed to be consistent with those observed in the north-eastern counties of Elgin and Nairn, and parts of Ross-shire, he apparently came to the conclusion that it was universally applicable in Scotland, and did not see the difficulties, or rather, we should say, the insuperable objections, which attend it when viewed in relation to other parts of the country.

Thus we read in the 2nd *Report*—"On the mainland of Scotland, at least in its eastern half, the boulders appear to have come over a wide extent of country in one and the same direction, viz., from the north-west. This inference had been drawn years ago from such facts as the finding of granite and mica-schist boulders in the counties of Fife, East Lothian, and Berwick, which must have come from the Scottish Highlands. But further and more striking proofs of this great north-west movement are afforded by the large boulders in the counties of Elgin, Nairn, and Ross-shire," which, it is concluded, "must have been transported from mountains far to the north-west." (Vol. viii. p. 143.)* This, however, is by no means certain, as we learn afterwards they may have come from the sides of the Great Glen, in a direction from W.S.W. to E.N.E.

We need only select a few of the instances given:—

In Ayton Parish, Berwickshire, a boulder of same rock as Cockburn Law, 10 miles to W.N.W. Also, pieces of coal found in a bed of sand. Nearest place where coal strata occur is in Mid-Lothian, 30 miles to N.W.

In Coldingham Parish, rounded masses of hematite, from East

* The references throughout are to the volumes of the *Proceedings of the Royal Society of Edinburgh.*

Lothian, 30 miles to N.W. At Blackadder, a boulder of blue whin, from Hardens, 5 miles to N.W. In Hutton Parish, blocks of a peculiar greywacke, from near Cockburn Law, 14 miles to N.W.

In the Parish of Dunse, a number of boulders, all carried in the same general direction from N.W.; among them porphyries from hills 3 to 6 miles distant, mingled with pieces of sandstone from the immediate neighbourhood to the west.

At Linton, East Lothian, a greenstone boulder from the Garlton Hills, 6 miles W. by N.

On Craiglockhart Hill, near Edinburgh, boulders of various kinds from N.W.—some of sandstone from a distance of only about a mile. At Alnwick Hill, near Liberton, in excavations for waterworks, a great variety of boulders from W. and N.W.; some of red sandstone, such as occurs at Grange and Merchiston, others of marine limestone, similar to that in Linlithgowshire, others of quartz, etc., which probably came from the Silurian rocks near Callander. Boulders of mica-schist, doubtless from the last-named locality, also occur on the Pentlands.

Near Kirkliston, Linlithgowshire, a boulder of Old Red conglomerate, probably from the neighbourhood of Callander or Doune, N.W.

Further west, a considerable number of conglomerate boulders are found near Dunmore, Plean, Stirling, Bridge-of-Allan, and Doune, which, the Convener remarks, "are interesting, as the position of the parent rock is known, viz., that band of conglomerate which traverses the country at Callander." (See, *e.g.*, 4th and 5th *Reports*, vol. ix. pp. 677-683, and vol. x. pp. 591-605.) And so the conclusion is confirmed—"General movement from the north-west."

Of course those who hold the theory of a great development of glaciers or land ice as more consistent with the facts point out that all these instances, on which Dr. Milne-Home founds so much, occur on the *eastern side* of the principal mountain chains, from which it can be shown that the boulders and striæ radiated in *all* directions—N., N.W., W., S.W., and S., as well as E. or S.E. Whenever we come to the *western* side of these mountains, the marks of glaciation are in a different direction, indicating a movement on that side *westward* out to sea. On this point, we think a single day's excursion by Loch Earn or Loch Tay, up the valley of the Dochart to the neighbourhood of the Black Mount,

and then down Glen Etive or Glencoe on the other side, is sufficient to convince anyone who fairly observes the facts.

Similar facts are presented very clearly in the south of Scotland—a district too little noticed in connection with glacial phenomena. The high grounds of Carrick and Kirkcudbright have evidently formed a centre of dispersion, from which the striations and boulders can be traced extending outwards on every side—to the N. and W., as well as to the S. and E. This, of course, is quite inconsistent with the theory of an ocean-current and floating ice or bergs.

If there had been a general inflowing current, laden with ice and boulders, from N.W., its traces should be most distinct and abundant on the west coast, which was first exposed to its impact. But it is precisely there that the evidences of ice-movement in a different direction are most conspicuous and unmistakable. It is on this western side of the country that the difficulties in regard to the theory favoured in these *Reports* thicken and accumulate.

Thus—(1) In the neighbourhood of *Loch Glashan*, near Loch Fyne, the Convener writes—"I was rather surprised to see the hills which sloped down to N.E. well covered with boulders, and also striated rocks facing N.E. and N.N.E." Again, near *Port Sonachan*, on Loch Awe—"I was rather surprised to find the boulders in such positions as to indicate that they had come from N.N.E. . . The rocks presented smoothings which faced N.N.E. . . I felt surprised at this direction as, when last year in the Hebrides and the west coast of Argyleshire, I had been accustomed to see that N.W. was the usual direction both of boulder transport and of rock striations." (6th *Report*, vol. x.) This observation, it is right to state with all respect, is not concurred in generally by geologists.

It had been stated in a previous *Report* * that "when boulders are on hills, they evidently indicate a preference for the sides of those hills having a N.W. aspect—a fact which seems to indicate the existence and prevalence of some transporting agent which could be more frequently and effectively stopped by the sides of hills facing N.W." (2nd *Report*, vol. viii.) But here are some stubborn and intractable boulders "indicating a preference" for a different side of the hill altogether! There was no help for it but

* Although it is apparent that the Convener did a great part of the work of drawing up the *Reports*, we wish to adopt, as far as possible, an impersonal style of remark by referring simply to "the *Reports*."

to admit that "this N.N.E. direction of transport [*i.e. from* N.N.E.] appears to characterize all the boulders and the rock striations at the Gareloch, Loch Gair, and Loch Awe," evidently including Loch Long, Loch Fyne, and Loch Etive, and to suggest that "in this district there may have been a current of floating ice moving in a S.S.W. direction." Also, "that when the Highlands of Scotland were covered by the sea up to a height of, say, 2,000 feet, and when they presented an archipelago of islands, there may have been currents moving in different directions, and these directions changing as the sea fell from one level to another." (6th *Report*, vol. x.)

What is this but giving up entirely the "general movement from the N.W.," and virtually saying there is no order or certainty in the matter? But we shall refer to these "abnormal currents" further on.

(2) In noticing the *Crinan* district, which seems to us in itself decisive of the whole question of sea or land ice, the *Report* affirms that "there is nothing to suggest the action of a glacier," and adheres to the view that the phenomena in question were the work of sea and "floating ice." And Mr. Jamieson is referred to as having "stated in one of his papers in the *London Geological Society's Journal*, that he found "smoothed rocks on the east side of this valley, and striations running N.W. and S.E." The Reporter admits he "did not see these markings;" but he adds, "they are not inconsistent with the theory above suggested as to the transport of the boulders." (7th *Report*, vol. xi.)

This reference to Mr. Jamieson's paper ("On the Ice-Worn Rocks of Scotland," *Quar. Jour. Geol. Soc.*, vol. xviii. 1862), which is well known as one of the standard papers on the subject, is exceedingly inaccurate, and can only be accounted for by supposing that it was written from memory, under an erroneous impression, and without taking time to verify it. Mr. Jamieson distinctly states that the rocks of this district, presenting "some of the most beautiful examples of glaciation" he had ever seen, are marked with "long rectilinear grooves running uninterruptedly onwards *from N.E. to S.W.* for many yards, with all lesser degrees of scratching and polish." The ridges, he says, present invariably their rounded snouts to N.E., and their more rugged outlines to S.W.; and there is "evidence that the agent which impressed these furrows moved obliquely *uphill*, mounting a slope of 700 or

800 feet." In short, he finds "the glaciation of the rocks of Knapdale looks as if the stream of ice descending Upper Loch Fyne (so great had been its volume, and so immense the *vis à tergo* impelling it onwards) had gone right out, over hill and dale, into the Sound of Jura." And, in his view, nothing short of ice "filling the valleys up to the brim, and covering the whole country in one great winding-sheet, will meet the requirements of the case." All this notwithstanding, when the Reporter visits Loch Swin, on the western side of Knapdale, he still thinks that the striæ and boulders indicate a movement inwards from N.W. (7th *Report*, vol. xi.)

(3) Coming to *Oban* and its neighbourhood, we find the clearest evidence that the channel of Loch Etive was once filled by a great mass of land ice moving westward out to sea. The *Report* admits that the rocky knolls along Loch Etive are all smoothed from the east, "indicating apparently the action of a glacier which had moved down the valley now occupied by the loch." (7th *Report*, vol. xi.) It is to be borne in mind that the whole of the upper part of this valley, from Bonawe to the head of Glen Etive, is formed of granite of several varieties, grey and reddish. It is perfectly certain that the glacier which once occupied the valley must have borne thousands of granite boulders, and deposited them in various positions near its termination and along its sides. Yet, in discussing the origin of such boulders around Oban, this seems not to be taken into consideration at all, but attention is constantly turned away to N. and N.W.

For example, the boulders in the little valley on the south side of Oban Bay probably came "from some north-westerly point." (7th *Report*, vol. xi.) The large granite boulder at the north end of the bay, known as the "Dunolly boulder," has a position close to the cliff, which raises a presumption that it came from W. or N.W. (4th *Report*, vol. ix.) Boulders on north end of Kerrera "probably came from same quarter." (*Ib.*) Boulders in the Pass of Brander are probably from the north, or "floated by ice flowing from N.N.W." (*Ib.*) A large granite boulder on the hills between Oban and Connal Ferry suggests a look towards Ben Cruachan on the east; but "there seems to be nothing improbable in the supposition that it may have been brought by floating ice from the north." (7th *Report*, vol. xi.) At Lailt, about 6½ miles from Oban, there is a perched boulder of considerable size. Judging from its

position, "the presumption is that it came from S.E., *i.e.* down the valley leading up to Loch Awe. *But it may have come from the N.W.*, as in that direction there is a valley by which it could have floated to its present position." (5th *Report*, vol. x.) Near it are fragments of another boulder, whose position also "suggested transport from S. or S.W. [S.E. ?], though the N.W. was not impossible." (*Ib.* p. 154.) Instead of carefully observing the facts of nature, and impartially recording what they seem to teach, does not this look like trying to bend these facts into conformity with a preconceived notion or theory ?

(4) We pass on to what is said regarding the *Great Glen*, or line of the Caledonian Canal. The facts collected regarding the transport of boulders at the northern or Inverness end of it—in the work of collecting which our esteemed vice-president, Mr. Jolly, had a large share—leave no doubt that the general direction of movement in that quarter was from S.W. to N.E., *up* the line of the Great Glen, and out to sea by Forres and Elgin. Of course this is different from the standard normal direction—according to these *Reports*—from N.W. It is admitted that "the boulders whose parent rocks are situated on the hills forming the sides of the Great Glen have moved, not E.S.E. (the normal direction), but E.N.E." Some modification of the theory must, therefore, be made to meet these facts. "There can be no doubt," it is added, "that when the sea stood at a height of, say, 2,000 feet above the present level, and with a general oceanic current from W.N.W., the current in *Glen-na-Albin* itself—*i.e.* between the walls of the valley—would be in the line of that valley, forming a deep fissure across the country running about N.E., and that the force of this abnormal current would be sufficient to carry boulders transported through it in a north-easterly direction till it united with the more general stream from W.N.W." (5th *Report*, vol. x.)

Thus, the number of "abnormal currents" increases ; one from N.E. to S.W. in the district embraced by Loch Long, Loch Fyne, and Loch Awe, and another from S.W. to N.E. through the Great Glen. It may be questioned indeed whether, if the line of the Great Glen caused any change in the direction of the "general oceanic current from N.W.," it was not far more likely to be from N.E. to S.W.—always towards the warmer latitude—than in the reverse direction, turning back to the colder conditions of N.E.. Apart from this, we may note that the latter supposed "abnormal

current" is quite inconsistent with the northern and north-western origin, which these *Reports* so resolutely insist upon with regard to the boulders on Kerrera and elsewhere around Oban; for how could boulders reach that neighbourhood from N. or N.W. across a powerful current—"sufficient to carry boulders, etc."—sweeping past it from the S.W.? It is also contradicted by the fact that in the southern half of the Great Glen the direction of boulder transport has been clearly to S. and S.W.* In fact, this change in the direction of transport along the line of the Great Glen—to N.E. at one end of it and S.W. at the other—is one of the leading facts subversive of the ocean current theory; for, of course, no such diverging ocean currents could originate in the centre of the glen.

"My idea is," we read in the 5th *Report* (vol. x.) "that whilst in the *higher* parts of the country the general traces of a W.N.W. current are everywhere distinct, in *low-lying* valleys the direction of the current would change in correspondence with the axis of these valleys."

May we venture to ask, how could this be? The supposed general oceanic current from N.W. (or "W.N.W.") would sweep across the country by all the cols or passes that were submerged, the higher ones allowing a less, and the lower ones a greater depth and volume of it to pass through them. When by the gradual elevation of the land, the higher ones got above water, the current at these points would simply cease; there could be no current where there was no continuous passage across; these valleys, so far as they continued to be submerged, would then become bays or inlets of "still water;" another current there, with a different direction, was impossible. Moreover, the "low-lying valleys," which would be longest under water and most continuously subjected to this wide-spread N.W. current, should be the most unlikely places to indicate currents in other directions; there, the traces of the general or prevailing ocean current should be most distinct, persistent, and uniform.

But we may note in passing, that, on the theory of the great deep-enveloping sheet of land ice pressing out on all sides from the high lands of the country, these changes of direction become quite intel-

* See Mr. C. Livingstone's "Notes on Boulders to West of Fort-William" (8th *Report*, vol. xi.), in which he shows that some of these boulders have come from the upper part of Glen Nevis, and others he believes were brought down the Great Glen from the neighbourhood of Glen Spean, etc.

ligible. During its maximum, or period of greatest prevalence, this ice-sheet would maintain a uniform course over obstacles, which, as it shrank, would suffice to turn it aside. At length, when it existed as a number of separate local glaciers, these would "correspond with the axis of the valleys" in which they moved—east, west, north, or south, as the case might be, which cannot be imagined of oceanic currents.

Again, though at the time of greatest submergence the current might flow across the higher cols and passes of the country, its main draught and volume would be across the more open low-lying valleys; and this would undoubtedly determine the course of the icebergs. An iceberg differs so little in specific gravity from water that it has a very great proportional draught—seven parts of its bulk being under water to one above it. Its course, therefore, is determined not so much by winds, or eddies, or side currents, as by the main, deep, arterial oceanic currents. In these it sits, and to these it clings. It is extremely unlikely, therefore, that, even during the time of greatest submergence, icebergs would find their way into little side-valleys or land-locked inlets, where the water could only have escaped by a high and narrow neck or pass, and where, consequently, the draught must have been quite inconsiderable; they must have been mainly restricted to the broad open channels and sounds of the country. Yet it is precisely in these narrow valleys and land-locked inlets, and on the steep slopes of high mountains—in situations the most difficult to imagine that icebergs could ever have reached—that their supposed relics and evidences, in the shape of boulders, are most abundant!

But, not to dwell longer on such points, we submit further that —as appears to us—this theory of floating ice or icebergs, laden with fragments of rock, and borne across the submerged land by a general oceanic current from N.W., *will not account for the facts* which these *Reports* have recorded.

(*a*) With regard to the boulders themselves, looking only at those of the central valley in the meantime, the principal fact, of which an immense number of instances are given, is that boulders, more or less worn and rounded, from the mountains in the west are strewn over the country to the east; and these far-travelled boulders are mixed with pieces of local rocks—*i.e.* from nearer sources, but still from localities to the west. It is needless to repeat instances, we refer to those already given at p. 238-9.

We know that similar facts are common in our own neighbourhood—boulders of the same kind of rocks as the mountains to N. and W. being mixed up plentifully with fragments of rocks from the immediate neighbourhood, sandstone, trap, shale, limestone, ironstone, in varying proportions, according to the locality.

Now, our contention is that the theory of a berg-laden ocean-current from N.W. will not account for these facts ; and is, indeed, directly at variance with them. Let us consider the matter for a little. An iceberg is a portion of a glacier or sheet of land-ice which has broken off and floated away after the glacier or ice-sheet reached the sea. All the pieces of rock, large or small, which it bears on its surface, or more deeply embedded in its mass, fell upon it, or were enclosed by it, and borne away during its slow and gradual progress over the land. From the moment it reaches the sea, it gains nothing more, adds no more to its rocky burdens ; on the contrary, it immediately begins to lose, dropping these burdens over the sea-bottom at less or greater distances from their parent beds. Itself in a state of gradual dissolution, its freight also is always becoming smaller and smaller. It is more than likely that it loses the greater part of the rocky fragments attached to it, or embedded in it, at an early stage of its progress ; those fixed in its under surface, as it melts away, soon drop off ; those on the top also speedily slide off and disappear ; so that nearly all the icebergs that are recorded to have been seen at sea, have been remarkable for the absence of rocky fragments of any kind. Indeed, there can be little doubt that the ice-sheet parts with a large portion of its stony freight *before* any part of it breaks off to form a berg ; as it protrudes from the land out to sea, it must be constantly dropping the pebbles and boulders with which it is charged. (See Geikie's "Text-Book.") So long as it floats, it is plain that the iceberg cannot pick up any fresh fragments of rock ; what reason is there for supposing it can do so when it touches the ground ? When it grounds on the sea-bottom, on a bank or some sloping ridge of submerged land, is it conceivable that it can, so to speak, recoup its losses by laying hold of and carrying away masses of rock from the land on which it has touched ? It is surely unnecessary to point out that ice as it exists in an iceberg is hard and brittle, not a yielding or plastic mass into which substances can be dinted by pressure, and to which they may thus be made to adhere

for a time. The shock of its stranding on the ground would tend to shatter it more or less, and to loosen from it any stones it was carrying, also to shatter any stones on which it struck ; but could not, in the least appreciable degree, enable it to pick up or attach fragments of rock to itself, far less so to incorporate them into its mass that it could carry them onwards to spots many miles distant from where it came into contact with them. The idea of icebergs thus acting as accommodating carriers and deliverers, not only laying down but taking up anew as they go along, really seems, the more we think of it, to be a wonderful hallucination. We may accept it as perfectly certain that, whatever icebergs may drop or leave behind them in their progress, they can take up nothing by the way; their "bill of lading," so to speak, was made up and closed before their voyage began.

Accordingly, if these icebergs, which are supposed to have produced the effects under consideration, took their rise, as is alleged, in some distant tract of land to N.W., from which even the boulders on the West Coast of Scotland and on the Hebrides have been derived, it follows that none of these boulders found on the eastern parts of the country can really have been brought from the neighbourhood of Linlithgow, Doune, Callander, Kilpatrick, Inveraray, or Bonawe, as has been imagined ; they must all have come from that distant tract where the ice was formed. Their resemblance to the rocks around Callander, Kilpatrick, Inveraray, etc., is a mere coincidence ; there is not the least likelihood that (*by such means*) they ever came from these points. Their occurrence, also, in a certain definite order in relation to these rocks of the country is purely accidental ; and it must be allowed to be wonderful that icebergs should have dropped fragments of rocks in a distinct order and succession, in a certain uniform position always, with regard to the rocks existing away down in the sea-bottom over which they were being carried !

We may confidently affirm, then, that this feature of the boulders—the mingling of nearer and more distant kinds which characterizes them—could never have been produced by icebergs. And this conclusion would be very much strengthened by a reference to the Boulder-clay, and its changes in colour and composition from point to point, in conformity with the subjacent rocks, but on this we do not at present enlarge.

(*b*) Further, not only the nature of the boulders and their rela-

tion to neighbouring rocks, but also the *positions* in which they are found, are directly opposed to this iceberg hypothesis. These *Reports* frequently call attention to the fact, which is worthy of very close attention and consideration, that "another common feature presented by boulders is that when they are longer than they are broad, the longer axis is parallel with the direction in which the boulder had been transported. Very frequently, also, when one end is sharp and the other end broad, the former points towards the direction from which the boulder has come." (4th *Report*, vol. ix., p. 705.)

This last particular, however, as we shall see, is very open to question.

All through these nine *Reports*, the boulders are described with reference to these characteristics—"striæ parallel to longer axis," and "sharpest end pointing" in such a direction. This fact regarding the position of boulders—so far at least as regards the correspondence of their longer axis with the direction in which they had been moved—may be taken as very generally established. But, accepting the fact, we entirely differ from these *Reports* in the conclusion drawn from it. "On the theory of icebergs or floating ice," it is said, "this feature is intelligible; on any glacier or ice-sheet theory it is not." (4th *Report*, vol. ix., p. 705.) We should say exactly the reverse; on the glacier or ice-sheet theory it is intelligible; on any theory of icebergs or floating ice it is not.

Can any one show that it is in the least degree likely that the stones dropped from, or left stranded by, icebergs, would correspond in the position of their longer axis with the direction in which the bergs were going? Manifestly, the stones would be dropped or left stranded in *all* positions; and it would be by the merest chance if one in a hundred corresponded with the direction of the berg's course. The berg itself may have changed its shape, its longer axis, even the side on which it floats, more than once during its voyage. What shadow of a probability is there that the stones it may deposit will have any uniformity of direction? None whatever.

This is so obvious that we begin to think the theory maintained in these *Reports* must be that the position of the boulders, as regards their longer axis, etc., is due to the subsequent action of the ocean currents. In the 2nd *Report* we read—"It was a remark of Hugh

Miller's that, on examining pebbles lying in the channel of a river, the great majority have their narrow ends pointing up stream. When once in that position, they retain the position longer than when lying broadside against the stream." (Vol. viii., p. 139.) Now, evidently this observation proves nothing with regard to boulders deposited by icebergs. The position of pebbles in a stream has really nothing to do with the matter—unless it be implied that these ice-borne boulders, many of them hundreds of tons in weight, and poised in precarious situations, had a certain uniform position imparted to them afterwards by the currents of the sea! This, we think, might be dismissed without further comment. But, first, we have grave doubts as to the accuracy of this observation, even though it be attributed to Hugh Miller. Masses of rock *in situ*, or that the stream could not move at all, may have their up-stream faces rounded or narrowed to some extent by the action of the current and the abrasion of sand and gravel, but that stones whose position *has been* affected by the current, could be arranged with their narrower and lighter ends pointing up-stream, seems impossible. We appeal to observation. In any movable body in a stream, if both ends be alike, will it not be rolled over and over, and if one end be sharper and lighter than the other, will not that end be wheeled round and point down stream? Then, secondly, we believe there is a mistake in the citation of the above passage. The reference is not given, and though we used to know Hugh Miller's writings tolerably well, we fail to remember in what part of them it occurs. We can, however, cite a passage from Hugh Miller of quite a different purport, and leave the reader to judge of the soundness of the reasoning, and its applicability to the point in hand.

In his well-known "Sketch-Book of Popular Geology," Miller refers to the fact of the pebbles and boulders of the Boulder-clay being scratched and grooved in the line of their longer axis, and argues that "the agent which produced such effects could not have been simply water, whether impelled by currents or in waves," for the smaller stones must have been *fastened* before they could have been scratched. "Even," he continues, "if the force of water could have scratched and furrowed them, it would not have scratched and furrowed them longitudinally, but across. Stones when carried adown a stream by the torrent, or propelled upward along a beach by the waves, present always their broader and

longer surfaces; and the broader and longer these surfaces are, the further are the stones propelled. They are not *launched* forwards, as a sailor would say, *end on*, but *tumbled* forwards *broadside*. They come rolling down a river in flood, or upwards on the shore in a time of tempest, as a hogshead rolls down a declivity. In the boulder-clay, on the contrary, most of the pebbles that bear the mark of their transport at all were not *rolled*, but *slidden* forward in the line of their longer axis. They were launched, as ships are launched, in the line of least resistance, or as an arrow or javelin is sent on its course through the air. Water could not have been the agent here, nor yet an eruption of mud propelled along the surface by some wave of translation." (Pp. 31-2.)

So far Hugh Miller had got fully thirty years ago. This passage proves that in his opinion water, "whether impelled by currents or in waves," could not arrange these stones or boulders longitudinally, or give them those markings which show that they retained their longitudinal position even when rubbed and pressed against obstacles which they encountered in their way.

This very general uniformity, then, between the longer axis of the boulders and the directions in which these boulders have come —accepting it as a fact—we find (1) is quite inconsistent with the theory of the boulders having been dropped by icebergs; and (2) could not have been imparted to them afterwards by ocean currents.

Accordingly, all the instances of uniformity or coincidence in this respect which have been brought together in these *Reports*, tell powerfully against the theory which these Reports adopt and defend. The same remark applies to the almost universal striation of the boulders in the line of their longer axis.

So also in regard to the instances which have been adduced of boulders having their "narrow ends" pointing backward in the direction *from* which they have come; we are convinced that in at least some of these cases there has been—quite unintentionally of course—a mistake in recording the fact. So far as our own observation goes, nearly all the larger boulders, and those whose position we may suppose to be unaltered since they were laid down, have their narrow ends pointing forward in the direction *towards* which they were being transported. This is plainly, as Hugh Miller said, "the line of least resistance." We might instance the Inverbeg boulder on the western side of Loch Lomond,

north of Luss (see *Transactions*, vol. vii., p. 174), the large boulder on the hillside above Arden, the "Jim Crow" boulder near Kirn (which the Reporter is certainly in error in stating has its narrow end pointing up the loch), the "black boulder" near Ashton, Gourock, and many others. So that the boulders alluded to as found on the western side of Knapdale, with their narrow ends pointing seaward, seem to us to prove exactly the reverse of what is concluded from them—not that they came in *from*, but that they were being moved out *towards* the western ocean. Take, for example, the "Dana boulder," a pear-shaped mass of from 70 to 80 tons weight, which rests on the shore of the island of Dana, on the northern side of Loch Sweyn. Here is a copy of the figure given of it in the Boulder Committee's *Report* (vol. xii., p. 781).

The supposition put forward in the *Report* regarding it is that it came in from the W. or S.W., and was progressing towards N.E. in that position! What natural agency could possibly incur such a waste of force as to move this mass *blunt end foremost?* Besides, what could be taking it to the north-east, in the face of a great "current" from that direction sweeping down Loch Fyne, as already admitted?

There is another point to which we wish to allude before closing. This is the frequent occurrence of boulders on the detached summits and steep slopes of hills, or on narrow ridges and knolls of rock, from which it would almost seem they could easily be dislodged—

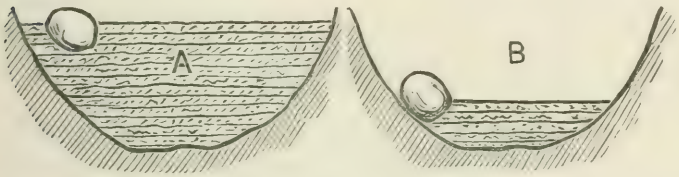
> "As if an infant's touch could urge
> Their headlong passage down the verge."

Numerous such cases are described in the *Reports*, and some explanation is offered of their having been left in such apparently

precarious positions. In one instance, near Oban, the Reporter says "the sides of the valley where these boulders lie are at present exceedingly steep, and it seemed marvellous that if they fell on the surface where they now lie they did not roll to the bottom." (7th *Report*, vol. xi.) In another place, he alludes to the difficulty of believing that the boulder *fell* into such a position from the end of a glacier. We may remark, however, that it need not have "fallen" at all—in fact, its being in such a position is good proof that it did not fall. It may simply have taken the ground while the glacier was shrinking, and then the gradually-diminishing ice-sheet being unable to move it further, it was left as it grounded. This seems to account better for the boulders being left on such narrow projecting points, than the stranding of icebergs, with any rocks they bore, in all possible positions. For in the first place, many of these knolls and summits are in such situations that it is impossible to see how an iceberg, even under the most skilful navigation, could get to them—one near Tarbert, on Loch Fyne, for example, being on a detached eminence quite surrounded by hills. (Vol. xii., p. 775.) And then, secondly, supposing the iceberg did get there, it is difficult to believe that such an unstable mass could leave any part of its rocky burden, if it had any, so exactly poised in that position. So great is this difficulty, indeed, that the Convener, without abandoning his main theory, propounds a subsidiary one to get over it. He suggests that "probably when these boulders arrived, the valley was filled with gravel, and that as the gravel was scoured out by streams, the boulders slowly subsided to their present position." (Vol. xi., p. 249.) In a subsequent *Report* this is explained more fully, and illustrated by a wood-cut, which we shall reproduce.

We read—"It is also a puzzle to conceive what kind of agent it was which could set these boulders upon the steep slope of a hill so gently and exactly as enabled the boulders to occupy positions of stability. Having been brought from a distance on a glacier or on floating ice, a boulder must in either case [?] have fallen with such violence as, by the reaction of concussion, to have slipped down any slope, even though far from steep. The only rational way, as it appears, of accounting for the position of these boulders is to suppose that the valleys became filled with detritus when the land was submerged, and that floating ice dropped boulders on the detritus. If the boulders were dropped near the

side of a valley, the boulders, as the detritus was removed by rain and mountain streams, would slowly and gradually sink till they reached the slope of the hill, and would then find a resting-place. This view is indicated by the following diagram, where A represents a boulder in detritus, and B the same boulder when the detritus was nearly all removed from the valley." (*Ib.*, p. 783.)



Now, with all respect, we should say that, granting all the conditions required, this is a most unlikely thing to happen. A boulder protects in some degree that on which it rests ; the detritus is gradually worn away on all sides of it by the denuding agencies, leaving it supported on a knoll or pillar of the detritus, like the earth-pillars at Botzen in the Tyrol, each with its stone a-top, as described and figured by Sir Charles Lyell. (*Principles*, vol. i., p. 337.) At length the pillar wearing away however slowly, becomes too slender to support its burden, and the stone *falls*, in a manner most unlikely to leave it nicely-poised on any narrow ledge underneath. Accordingly we find it stated by Sir Charles that "many of the fallen blocks, once the cappings of pillars which have disappeared, are now seen in the bed of the torrent." (*Ib.*, p. 338.) This is the natural history of a boulder resting on detritus; and, indeed, it is illustrated by an instance, given in the 6th *Report*, of a large boulder in the Inveraray district, north of Loch Fyne. "It was resting," says the writer, "on a knoll of gravel, at some distance from any hills. At first I was puzzled to account for its position being so exactly on the apex of the gravel knoll. It struck me eventually that its great size and weight had been the means of protecting by covering the knoll on which it originally had been dropped. The denuding agencies which could loosen and sweep away the gravel and sand in the surrounding parts of the valley, probably did not move the boulder, and so would leave it in its original position, or nearly so." (Vol. x., p. 581.) Exactly ; but how is it to get down at length, gently and easily, to its

narrow ledge of rock? Again, as regards the conditions—not to enlarge on the enormous quantities of detritus required by the theory now under consideration, and the question whence and by what means these were accumulated (for mere submergence does not *create* detritus)—a fatal objection to the theory is that multitudes of the boulders whose position is sought to be explained are not in valleys at all, but on isolated hill-tops, on the shoulders of high mountains, and on steep slopes overlooking wide moorlands, or the sea; so that from every point of view the explanation is incredible, and starts greater difficulties than it was intended to remove.

We had some observations to offer on the N.W. current, and the submergence of the land, so frequently alluded to in these *Reports*, but must reserve these till another opportunity.

No. XXII.—On Some Boulders near Arden, Lochlomond. By Dugald Bell. With a Plate [No. V.].

[Read 12th January, 1888.]

Though the Boulder Committee of the Royal Society of Edinburgh now rest from their labours, there are doubtless, in various parts of the country, many boulders which, notwithstanding all the care taken, that Committee have not included in their valuable *Reports*. One of these, a large and prominent mass of mica-schist on the hill above Inverbeg, near Luss, was brought under the notice of the Society a few years ago. (See *Transactions*, vol. vii., p. 172.) I wish now to call attention to one or two others, also on the western side of Lochlomond, but farther south, viz., on the hill known as *Gowk Hill* (called by the Ordnance Survey, *Cock Hill*), behind Arden.

At this point there is, as the Convener states in one of the *Reports*, "a low valley which runs up from the loch in a westerly direction. The summit level of the valley is about 150 feet above the sea. Along the south side of the valley," he continues, "a number of boulders, chiefly of primitive rocks, have been deposited. They are at a height of about 94 feet above the sea. As usual, the most frequent position is here, as elsewhere, N.W. and S.E. for the longer axis, and the sharpest end towards the west." (4th *Report*, vol. ix.) This last statement, we are convinced, is a

mistake, and we shall refer to it later on. Meantime, we may note that the position of many of the boulders is much higher than that mentioned in this *Report*, instead of 94, being from 200 to 400 feet, and in the instance we have now to describe, about 600 feet above the sea.

The contrast between the northern and southern parts of Lochlomond has often been pointed out. In the northern part, where the lake extends among the old schistose (Lower Silurian) rocks, bare rugged hills come steeply down to the water's edge, with, in many places, little or no margin of alluvial soil at their foot. But in its southern part, where the lake expands over the softer formations (Old Red and Calciferous sandstones), the banks retire with gentler undulating slopes, and there is frequently a considerable stretch of almost level ground bordering on the shore. This is especially the case where a stream falls into the loch; if its course has been over the softer rocks referred to, it forms a much larger delta than those in the upper part of the loch, as may have been seen at the mouths of the Endrick and Fruin. In fact the delta of the Fruin occupies a great part of the "low valley" running westward behind Arden, referred to in the *Report* from which we have quoted.

This valley may be said roughly to mark the junction of the slate and sandstone rocks, having slate on its northern and sandstone on its southern side. The hill behind Arden, which forms the southern boundary of the valley, deserves a more careful investigation than we have yet bestowed upon it. It is a continuation of the same strata that appear at Balmaha on the opposite side of the loch, where a hard cherty limestone, or calcareous sandstone, much metamorphosed, is overlaid by a massive conglomerate of the Old Red Sandstone. This ridge extends across the loch, like the fragments of a ruined wall, in the chain of islands from Inch Cailleach to Inch Murren, and re-appears in the hill behind Arden, where it again mounts to a height of from 800 to 900 feet.

It is on the northern slope of this hill, at about 600 feet above the sea, that the boulders now under notice occur. There are three of them within a short distance from each other, all composed of contorted mica-schist, in which the weathering brings out the folding and crumpling of the layers very distinctly. The largest is a mass measuring 15½ feet long, 9 feet broad, and 7 feet high,

and must therefore weigh about 73 tons. Its longer axis has a position of N.W. to S.E., or more precisely 10° N. of W. to 10° S. of E. One end is sharper and more tapering than the other. *The blunt end is towards the N.W., and the sharp end towards the S.E.* This corresponds with the position of the Inverbeg boulder already referred to.

The slope of the hill is here of considerable steepness, but well covered with soil and grass, and overgrown with wood. The large boulder rests in a slanting position, its sharper end being higher than the other, as if it were being carried diagonally across the face of the hill when its progress was arrested.

About a hundred feet lower on the hillside is a small rounded boulder of granite, rough-grained, with large crystals of flesh-coloured felspar. Similar boulders have been observed on Benbowie hill near Helensburgh ; and a large one was dug out in levelling a part of the old Luss road a few years ago. Boulders of a similar granite have also been found on the opposite side of the Firth, near the Cloch Lighthouse ; indeed, they are not uncommon in the Clyde district. They seem to have come from the neighbourhood of Inveraray ; but some observers are disposed to trace them as far afield as Ben Cruachan.

Further down the hill, near the old castle of Banachra, other boulders of mica-schist occur—one a cubical mass of considerable size. They are also numerous on the N.W. face of Benbowie and on the hill between Helensburgh and Glen Fruin.

But the largest boulder in the district is the Callendoun boulder, also of mica-schist, first described by Mr. R. L. Jack, formerly of the Survey. Its dimensions are 28 ft. long, 18 ft. broad, and 7 ft. high, weighing therefore about 270 tons. Its position is about a mile to N.W. of Banachra, and fully 200 feet above sea-level. The direction of the longer axis is similar to those already mentioned—N.W. and S.E., with the heavier end to the N.W. In the 2nd and 10th *Reports* of the Committee it is stated to have the "sharp end to west," but this is certainly a mistake. It rests on the western bank of a small stream, running from N. to S. to join the Fruin, and stretches nearly across the ravine which the streamlet has formed. It appears at one time to have formed an obstruction to this little stream or "burn," for an old channel is seen at the western end of the stone, which the water may have occupied from time to time ere the present channel at,

and partly under, the eastern end, had been sufficiently deepened. Of course—though we do not make much of this—other things being equal, the main channel would be formed at the narrowest end of the rock, where the obstruction was least. But the fact does not need any such consideration to support it, being quite plain to all who choose to look at it. The boulder has lately been visited with special regard to this matter. Beyond all doubt its broad end—like the stern of a huge ferry-boat—rests on the western bank of the stream; and its narrow end—like the bow of the same boat—projects eastward over the bed of the stream. The statement in the *Report* is therefore, as we have said, a mistake. The position of the longer axis may be laid down more exactly as W.N.W. and E.S.E. [See plate V.]

The Convener of the Boulder Committee thought it more probable that this boulder came from the N.W., in the direction of the Gareloch and Lochlong, than that it should have been carried down Lochlomond and then "moved at right angles to westward to gain its present site." In this we quite agree with him, not from any belief in a "general N.W. current," but simply because there is good evidence that the glaciation of this valley, or pass, was in this direction —viz., from N.W. If, however, the "sharp end" of the boulder had been to westward as stated in the *Reports*, we should have thought it a point in favour of the opposite view—viz., that the boulder was being moved *towards* the west. For, as the Convener himself remarks, when boulders are "pear-shaped" it indicates that "one end has probably undergone more friction than the opposite end." (10th *Report.*) We presume there can be no question that the end which was being moved *foremost* would undergo the greater friction, and become the sharper and more pointed in form. If there is anything at all in the position of the boulders; if the numerous instances of coincidence between their longer axis and the direction in which they have come show that they were probably left in the position in which they were being moved; if it is more likely that they would be left in that position than turned in exactly the *contrary* way, then undoubtedly the narrow end must point in the direction in which they were being moved. And this for a double reason. Not only is the foremost end made narrow by attrition; but being so, tends to *keep* it foremost, which is plainly the position of least resistance. We cannot imagine any natural agency sufficient to move these boulders at all, yet continuing to move

them in the most disadvantageous position, with the greatest expenditure of force, in the line of greatest resistance, or broad end foremost.

So far as we are aware, none of the many observers who have written on glaciers state that there is any general uniformity of position in the fragments of rock carried forward by these icy streams, either resting on their surface or in some degree embedded in their mass. But neither do the observers state that there is no such uniformity : the point merely seems not to have been specially under their notice. Yet it appears obvious that the motion of the glacier must have a certain definite effect on the position of the rocky fragments, for these are not scattered confusedly over the surface of the glacier, but arranged in certain well-marked lines (lateral and medial moraines) curving according to its course, and this could hardly be without some effect on the position of every stone in the series. It is admitted that the smaller stones in the Boulder-clay, when striated at all, are almost invariably so in the line of their longer axis. They may have certain cross-scratches, indicating that their position has shifted a little from time to time ; but this is their main general line of striation. Also, the striation is most noticeable at their sharper end. They have evidently been pressed forward lengthways and sharp end foremost ; "fixed like gravers' tools in the ice," they have grooved and indented with long, continuous scratches (striæ) the underlying rock-surfaces over which they have passed. (*Prestwich.*) The same remarks, as regards position, must obviously apply to the larger boulders as well.

Since writing the above, we have met with an interesting observation regarding the Mueller Glacier, New Zealand. Mr. F. W. Hutton, writing from Christchurch, N.Z., 22nd March, 1888, says :—"All through the lower portion of the glacier the veined or ribboned structure is well marked, running nearly in the direction of the glacier." Then, after alluding to another system of coarser veins seen at the terminal face, but not higher up on the glacier, he continues—"The ice here contains in places numerous angular stones, principally of slate, scattered irregularly through it, and these fragments always have their broad, or cleaved, surfaces parallel to the smaller system of veins. These stones have no doubt entered the ice through the numerous moulins and crevasses which are found higher up the glacier, but as they are not found

in bands nor in pipes they must have been moved in position by the flowing of the ice." (See *Nature*, 24th May, 1888.) Further observations of this kind are much to be desired.

The instances of conformity between the longer axis of the boulders and the direction in which they have been moved are sufficiently numerous to be noted by observers as the common or normal position. (See the Committee's *Reports*.) We submit that every instance of such conformity makes it *more probable* that the boulders were being carried forward by glaciers than by icebergs; for the latter would, of course, leave their rocky burdens in every conceivable position. So long as they were being moved forward by land ice, there is reason to believe there might be some uniformity in their position; but as soon as they became part of a floating mass or berg dropping its rocky burdens in any way, changing its shape from time to time, and touching obstructions at every possible point, all likelihood of any such uniformity was at an end. But, though so frequent as to be considered the common or normal position of the boulders, this coincidence between the direction of their longer axis and that in which they have been moved is by no means invariable or without exceptions. In the very group of boulders now under notice the two smaller ones do not coincide in position with the largest one, nor with each other. They seem to have fallen or been left in their places without any definite arrangement. Nor indeed, when we consider the circumstances in which they must have been left by the melting and retreat of the ice, even assuming it was land ice, can we expect an absolute uniformity in this respect. What Dr. Prestwich has said to explain the mixture of striated and unstriated fragments in the Boulder-clay applies to this also:—"As the terminal moraine of a glacier contains both the angular, unworn fragments fallen from the steep precipices bounding the glacier in its course, together with the ground, worn, and scratched fragments held and carried down in the bottom ice over the rocky bed of the glacier, this moraine consists of a variable proportion of rough, angular fragments, with a certain proportion of worn and striated fragments, the relative numbers varying, of course, according to the character of the country traversed. ("Geology," vol. i., p. 178.) From the numerous instances of conformity to which we have referred, chiefly remarkable, we think, among the *larger* boulders, it looks as if these, being more deeply embedded in the ice and

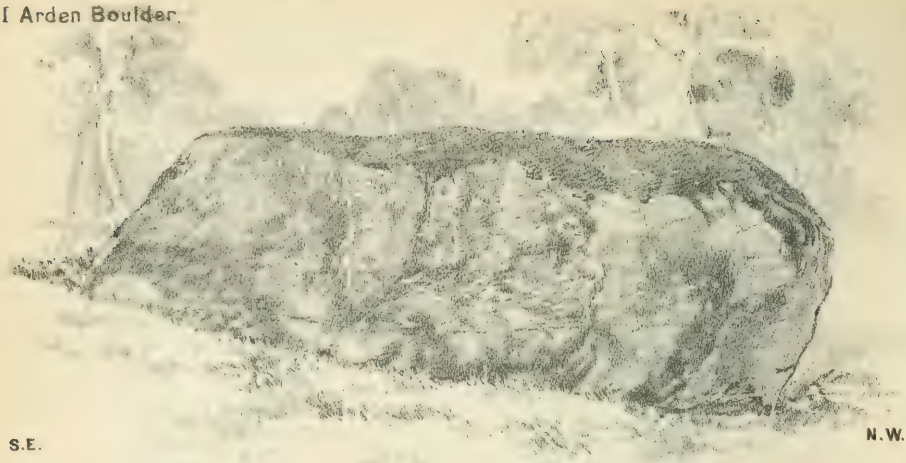
sinking gradually with it as it shrank, were ultimately left in the positions in which they were being moved; while many of the smaller ones fell in diverse directions from the melting and diminishing surface of the glacier. A general uniformity of position in the boulders seems a cogent argument against the action of icebergs, but even numerous exceptions to that uniformity seem no argument against the action of glaciers. Land ice could produce both the general uniformity and the occasional exceptions; floating ice could not produce the uniformity. We might add that neither could it produce the fine regular striæ on subjacent rocks as well as on the transported fragments, and the mingling of near and distant kinds of the latter; but to this we have referred elsewhere.

Whatever doubt there may be as to the direction in which *some* boulders have come, there can be none with regard to these Arden boulders: no one can possibly imagine that they came from S. or S.E. They were certainly being carried from N. or N.W.; and, with regard to the principal one, there can also be no doubt as to its longer axis being in the direction of transport, and its narrower end pointing S.E. This, as far as it goes, and taken in connection with other similar cases, is, we think, in favour of land ice.

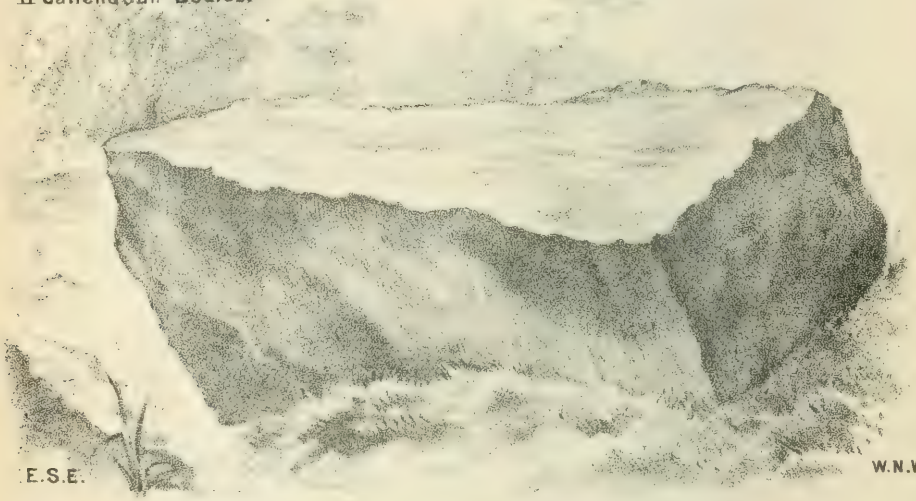
As we remarked with regard to the Inverbeg boulder, "the higher such boulders are found—especially those of large size—the greater is the difficulty of supposing them to have been borne by bergs. For, keeping in mind the small floating power of ice—only about one eighth of the mass being above water and seven eighths under it—this would necessitate a very great submergence; in the case before us probably not less than twice the height at which the boulder is found. [The Inverbeg boulder is about 1,000 feet above sea-level.] And a submergence of 2,000 feet, or thereby, would so narrow the land surface of our country that we may ask, where could such extensive snowfields and icefields be found as were required to produce bergs of the size indicated?" (*Transactions*, vol. vii., p. 175.)

We do not deny that some boulders may have been carried by icebergs; but we believe they were comparatively few in number, and restricted to the lower levels of the country. As Dr. A. Geikie observes—"Erratic blocks have probably in the vast majority of cases been dispersed by land ice, and not by floating ice." He also remarks that though brought down originally by

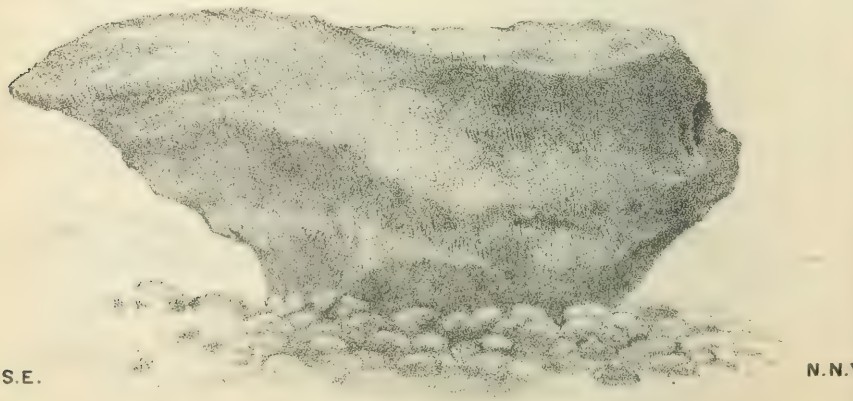
I Arden Boulder.



II Callendoun Boulder

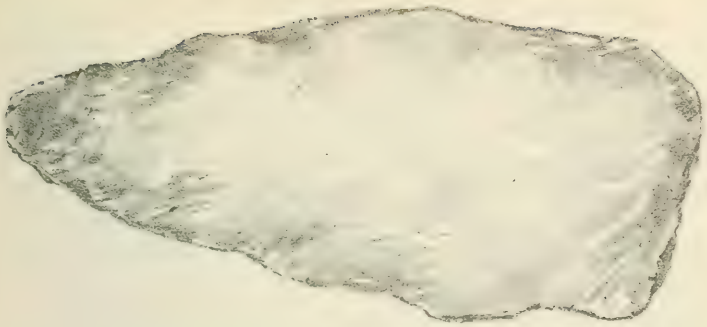


III. "Jim Crow" Boulder Kirn.



I

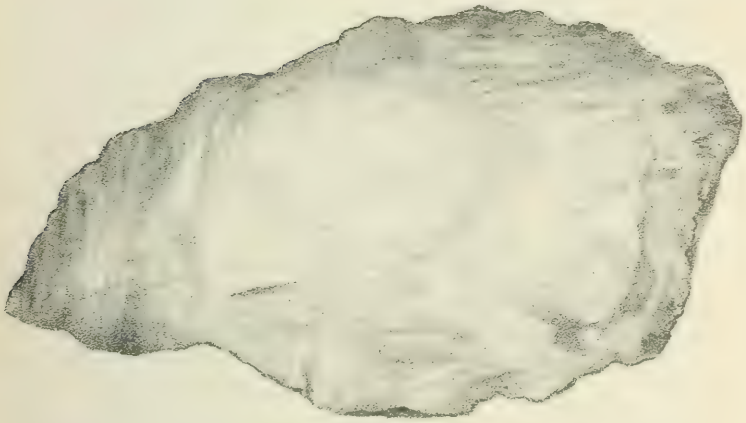
Surfaces



S.E.

N.W.

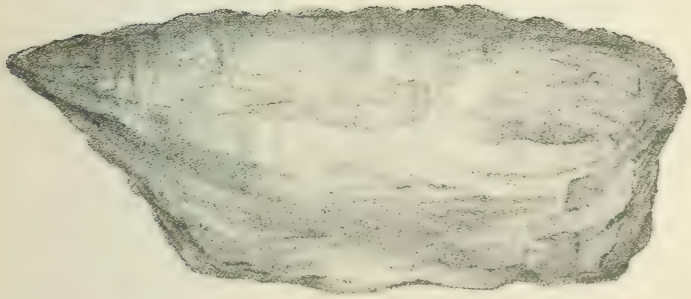
II



E.S.E.

W.N.W.

III



S.S.E.

N.N.W.

land ice, "they may in some cases have been shifted about by floating ice" during a subsequent period of partial submergence. ("Text-Book," p. 897.) In any case, we believe such sea-borne boulders will be found only far down in the main valleys, and near the present coast-line of the country; and will show only in the rarest instances, and by accident, so to speak, any relation between their position and the direction in which they have come.

[Note.—On one point we may add a note before closing. It may be asked, if the glaciation of this pass or valley between Arden and Helensburgh was from the N.W., why do we not accept it as evidence in favour of a general inflowing current from the N.W.? We reply, because it is quite a local phenomenon. A little further down the Firth the glaciation was as clearly from N. and N.E.; and in parts of Ayrshire it was even from S. and S.E.—dependent entirely on the position of the locality in regard to the principal neighbouring mountain ranges.

There is good evidence that the ice at this point—from the great coalescing glaciers of Loch Long, Loch Goil, and the Holy Loch—so filled the present channel of the Clyde that it passed straight over the hills on either hand into the country beyond. It passed to S. and S.E. over the hills behind Greenock and Port-Glasgow, striating the hard trap rocks there in a most remarkable manner; and also, in a similar direction, over these hills between Helensburgh and Loch Lomond. If the probable mass of the Loch Lomond ice be urged as an objection to this, we should reply that *it* also partook of this local S.E. movement; towards the southern end of the loch, it seems to have been largely deflected eastwards into the Balfron valley and through the "gap of Lennox," along the flanks of the Campsie hills. In short, the glaciation was south-eastwards here, because this tract is on the south-eastern side of the main mountain ranges. The lower part of the Firth of Clyde was so choked with ice flowing south and south-westwards from the same ranges, and from the southern uplands, that the ice at this point could not find egress in that direction; so it gradually extended eastwards, and held its way across the main valleys of the country towards the German Ocean. But from this fact no inference can be drawn in favour of a great inflowing current from the N.W. sweeping over the country generally. June, 1888.]

No. XXIII.—Some Notes on the Geology of the District about Tarbert, Lochfyne.

By Thomas Scott, *Corresponding Member, Assistant Naturalist to the Fishery Board for Scotland.*

[Read 10th February, 1887.]

Having been located for some time in Tarbert, Lochfyne, I had an occasional opportunity of making observations on the geological features of the district, but as there is in its general aspect so much the appearance of sameness, some time elapses ere one begins to become acquainted with details. Though the leisure at my command did not permit of an extensive examination, still the following notes on a few objects which came under my own observation may not be without some general interest.

The rocks about Tarbert, when somewhat closely examined, are seen to vary very much in their general aspect, in their structure, and in the amount of folding they have undergone. In some places they present a comparatively even surface, while in others disintegration has proceeded in such a way as to give them an exceedingly ragged appearance. This diversity in surface configuration is of course owing very much to difference in mineral structure, and while there are instances where there is little apparent folding, there are others where the convolutions are of the most complicated nature, and where the beds are very much contorted, besides being built up of harder and softer laminæ. In such cases, and where the rock has been subjected to a great deal of weathering, the appearance presented is sometimes very fantastic.

Among the hills to the northward above Glen Rolloch, and about an hour's walk from the village of Tarbert, is a little loch called Loch-na-Kenna. At its eastern end where the rocks rise abruptly from the strand, they are very unequal in their structure, very contorted, and weathering has imparted to them a strange and grotesque appearance. In some places there are beds of a coarse-grained sandstone apparently little altered in structure, which alternate with others of a bluish schist, and at the north-east corner with thin calcareous beds. The rock, which is of a brownish colour, is not truly crystalline, though rather hard. It contains,

besides calcium carbonate, a good deal of carbonate of magnesium and some carbonate of iron. From the proportions in which these occur they are seen to agree very closely with some forms of ankerite. The following is an analysis of one of the specimens I obtained—$CaCO_3$ 52·94. $MgCO_3$ 35·16. $FeCO_3$ 11·60. SiO_2 (sand) 30. J. D. Dana, in his "System of Mineralogy," 1883, p. 683, gives an analysis by Kühn of a specimen of ankerite from Schneeberg, as follows:—$CaCO_3$ 52·64. $MgCO_3$ 36·35. $FeCO_3$ 12·40. $MnCO_3$ 0·34. In the Loch-na-Kenna specimen there is therefore a nearly similar proportion of calcium carbonate and scarcely 1 per cent. less of magnesia and iron, but no manganese, as in the Schneeberg specimen, where it reaches only 0·34 per cent. There is a little silica, probably due to the presence of minute quartz crystals. Besides agreeing so closely in mineral structure with the ankerite from Schneeberg, it fulfils another condition given by Dana as a characteristic of this mineral in dissolving with very little if any effervescence in the presence of cold H.Cl. With dolomite, on the other hand, under like conditions the effervescence is violent. This seems therefore to be a true ankerite. Possibly this mineral is widely distributed among the rocks about Tarbert, for in a specimen of tourmaline from White Shore Bay, East Loch, Tarbert, which I submitted to Mr. John Young, F.G.S., he says that besides tourmaline and quartz "there is apparently dolomite present, which is seen passing into ankerite."

On the west and north-west sides of Loch-na-Kenna, which are quite shallow, and where water lilies are very plentiful, there is an extensive accumulation of mud. In some places it is moderately firm, in others exceedingly soft, so that great care is necessary when walking over it, otherwise one may find oneself up to the knees in sticky ooze before he knows where he is. Nearly buried in this mud are the trunks of several apparently large trees, though how they came there is a mystery. The nearest living trees are, I think, growing down in Glen Rollock, so that probably those lying prone in and about this loch are the mementoes of a time when the surrounding hills were clothed with a greater wealth of vegetation than they are now able to support. There are other points of interest connected with this little loch which I must pass over in the meantime.

Limestone, as has been pointed out by Mr. James White, in his paper read to this Society in October, 1885 [*Transactions*, vol. viii.

p. 111], is by no means uncommon about Tarbert, being found in massive beds as well as in veins, and also entering largely into the composition of many of the rocks in the neighbourhood. In some places it occurs as a highly crystalline and nearly pure calc-spar, though it very often contains iron and magnesium carbonates. The remains of a fine vein are seen by the roadside a little east of the "Inverary quay," though now very little of it is left. A bit of it which I had analyzed gave the following results—$CaCO_3$ 92·35. $MgCO_3$ 2·80. $FeCO_3$ 4·26. SiO_2 ·59.—so that it may be considered a ferrocalcite. The analysis of a specimen by Hunt, as given by Dana in the work already quoted, p. 683, is $CaCO_3$ 93·90. $MgCO_3$ 1·59. $FeCO_3$ 4·64. It differs little from the above, except that the Tarbert specimen contains 1·21 more of magnesium carbonate.

Iron in the form of pyrites also occurs in this district. I found it somewhat plentiful in some rocks lying between the "Columba wharf" and the old concrete pier, and which were being blasted in connection with the carrying out of the new drainage scheme.

Several specimens of menaccanite were also found during last summer, most of them being got on the south side of east Loch Tarbert. This mineral was first observed by my friend, Mr. Robt. Hamilton, C.E., and, as far as I know, occurred in every instance in detached boulders of quartzose schist.

Besides the common white quartz so abundant in many of the rocks around Tarbert, a semi-transparent form having a vitreous lustre occurs, and in several places it is found combined with iron in the form of ferruginous quartz, but not very plentifully. In some of the rocks tourmaline is seen to be exceedingly abundant. It usually occurs in long crystals, generally not thicker than a small needle, which are scattered more or less plentifully through the matrix. A cross section of a crystal shows a somewhat triangular outline, but when closely examined it is found to be very obscurely 9-sided. Sometimes accumulations of pure crystals are met with, as if filling up what may have been cavities in the rock. Though generally crystalline, these occasionally assume an amorphous form, the crystalline character being almost entirely lost, but in the surrounding quartz or calcareous material with which the tourmaline is, in this form, usually associated, crystals are seen branching off in different directions. It is connected with this form of tourmaline that what appears to be dolomite passing into ankerite, previously referred to as observed by Mr. Young, is

seen to occur; this amorphous condition probably resulting from the mineral while in a crystalline state becoming altered through combination with other elements, and not *vice versa*. A careful analysis might determine this.

Wherever tourmaline is abundant in the rocks, they present an extremely ragged appearance, and seem ill adapted to withstand the tear and wear to which they are subjected by the weather. In the neighbourhood of Garvald Point, where I had an opportunity of making some observations, the tourmaline schists are seen to extend from the surface down to a little above high-water mark. Below them, and extending as far at least as low-water mark, the rock is quite different, being harder, much more uniform in structure, and containing a good deal of quartz, and therefore less easily weathered. The contrast between the two rocks is very striking, the upper being rugged and weather-worn, the lower exhibiting a comparatively even and uninjured surface. But though thus different in structure, the boundary line between them is by no means clearly defined. I have noticed in other places in the neighbourhood where these rocks are exposed, as round the head of East Loch Tarbert, that they retain their relative positions. These tourmaline schists have been observed on the Cantyre side of the loch, as well as on the Knapdale side.

A short way round from White Shore Bay, towards "M'Arthur's Island," East Loch Tarbert, a thick bed of talcose schist is observed. It is well tilted up, and being comparatively soft, the water has formed a deep indentation on both sides of the headland across which it passes diagonally. Possibly the time is not far distant when this headland will have become another "Skeiran," round which the wintry waves will rear their whitened crests. This schist, however, though not a pure soap-stone, evidently contains a good deal of talc, as it feels very "soapy" when rubbed.

Mr. White, in his paper on Tarbert, already referred to, mentions some interesting phenomena peculiar to the "glacial period" as exhibited in the form assumed by the rocky knolls seen everywhere in the district, and in the occurrence of numerous perched blocks. There is also evidence that the laminated shell-bearing clays of that period—clays which were so fully exposed in section at Garvel Park, Greenock — were at one time extensively developed here. As long ago as 1869, Mr. David Robertson, F.G.S., described a shell-bearing clay, which he examined at the

north corner of East Loch Tarbert, and which was acknowledged to be of Post-tertiary age. I have from Mr. Robertson's description been able to identify this deposit. It is seen on both sides of the stream which in his paper is called the "Black Burn," and can be followed for some distance up from the shore, more especially on the south side of the stream. The same deposit can be traced nearly all round the shore at the head of the "Douchlan" —the local name for this part of the loch—into which the Black Burn runs, and when the fishermen happen to dig holes here at extreme low water, for erecting poles for net-drying purposes, this clay is generally turned up, and the same thing occurs at other places round the head of the loch. Last year when the drainage operations were being carried on, a trench more or less deep was cut from a short way below the "Inveraray quay" to the old concrete pier—that is, along a good part of the south shore of the loch—where for a considerable distance on both sides of M'Tavish's boat-building shed, fossiliferous Post-tertiary clay was dug into—the clay being in some places mixed with a good deal of sand. Among the shells turned up were many examples of *Pecten Islandicus*, as well as of *Astarte borealis*, but I did not notice any of these shells about "Douchlan," the only truly boreal shell I saw there being *Tellina calcaria*. But I did not examine this clay very minutely, for the work in connection with the Fishery Board's investigations required all the attention that could at the time be given to it. Besides this extensive range of these shell-bearing clays round East Loch Tarbert, similar clay containing *Pecten Islandicus* was observed on the shore of Lochfyne in a little bay separated from the White Shore by the low ground stretching back from Garvald point. Whether this clay extends across to the White Shore or not I cannot say.

From the fact that these clays extend so far round East Loch Tarbert, it requires, I think, no great stretch of imagination to conceive that they once occupied the greater part at least of the area now covered by the loch. Whether its bed had been previously scooped out by ice action or otherwise may not be so easily determined, but, however it may have been formed, it seems to have been gradually more or less filled up with deposits of mud and other debris during the ice age, till a somewhat higher level was reached than that of the present high-water mark; and that afterwards these deposits were worn down and carried away, possibly to form part of the submarine banks in Lochfyne, while only

around the margins of East Loch Tarbert were patches left to indicate what was once a comparatively large land surface.

In one of our hauls with the dredge in Lochfyne, a little south of Tarbert, and in moderately deep water, a valve of *Panopœa Norvegica* was fished up, but its occurrence was so unusual, and it had such an old-world look about it, that we refrained from giving it a place in our list of recent marine forms. It may perhaps have been washed from the clay which was carried out by the sea from East Loch Tarbert.

In concluding these remarks I wish to acknowledge the kindness of Mr. John Young, F.G.S.—who is always ready to lend a helping hand to honest seekers after knowledge—for naming the specimens of minerals from Tarbert, and for information connected therewith. The analyses of ankerite and ferrocalcite were made by my son, who is indebted to Mr. J. W. Biggart, F.C.S., F.I.C., public analyst for Greenock, for valuable hints on correct quantitative estimation.

No. XXIV.—Some Notes on a Bed of Shell-bearing Clay at Roxburgh Street, Greenock. By Thomas Scott, *Corresponding Member, Assistant Naturalist to the Fishery Board for Scotland.* With a Plate [No. VI.].

[Read 8th March, 1888.]

Almost fifty years have now passed away since the late James Smith of Jordanhill, in a paper read to the Wernerian Society, "On the Elevated Marine Beds of the Basin of the Clyde," called attention to the existence of a laminated clay containing marine shells which had been exposed near Greenock through the operations connected with the construction of the Caledonian Railway from Glasgow. This clay occurred in the vicinity of the Cartsdyke Station, and was therefore probably a continuation of the extensive deposit which has been exposed during recent years—first when the Graving Dock at Garvel Park was formed, and latterly and more extensively, during the formation of the James Watt Wet Dock at the same place.

Although the number and variety of the organisms collected from the clays which were exposed while the excavations for the James Watt Dock were being proceeded with greatly exceeded

those found anywhere else in Clydesdale, and a very valuable and interesting chapter was thus added to the Post-pliocene geology of the West of Scotland, yet in one way the interest attaching to the discovery of the Cartsdyke clay was greater, for at a time when this department of the science was not so well understood as it is now, a notable addition was here made to the rapidly accumulating evidence that within comparatively recent times a very considerable change had taken place not only in the climatal conditions of the British Islands, but also in the relative levels of sea and land. The Cartsdyke deposit was 50 feet above the present sea-level, while the shell-clay at Garvel Park was in part only a few feet above, and very much of it considerably below, the same level.

During the construction of the branch line of the Glasgow and South-Western Railway which connects the main line with the new docks at Garvel Park, a clay containing the usual boreal shells was cut into a little west of the Bogston Station of the Caledonian Railway. This clay had an elevation somewhat similar to that at Garvel Park, and was possibly a continuation of it. Another Post-pliocene clay was cut into during the excavation for a sewer across what is locally known as the "Battery Field," and near the junction of the High and Low Gourock Roads. The same bed was subsequently exposed at the west end of Westbourne Terrace and behind the garden attached to the old Gourock Toll-house, where sand was being dug out for building purposes. (A short paper on this deposit was read to the Society by Mr. Thomas Steel, see *Transactions*, vol. vi., p. 261.) This deposit also was very little elevated above sea-level, so that the clay which was exposed at Cartsdyke, and examined and described by Mr. Smith of Jordanhill, was, until quite recently, the highest recorded in the neighbourhood of Greenock.

In the construction of the extension of the Caledonian Railway, which is at present being carried out from near the Cathcart Street Station, Greenock, to the Steamboat Quay at Gourock, extensive excavations in the form of tunnelling and open cutting have had to be made. One of these open cuttings is at Roxburgh Street, Greenock, where the old Highlanders' Academy stood [See Plate vi., plan of Greenock.] In making this cutting a bed of sandy clay, containing the remains of marine and other organisms, has been exposed, and appears to be of Post-pliocene

Scale of Half a Mile.
0
1
2
3
4 Furlongs
PART OF THE PLAN OF GREENOCK
TO SHOW THE POSITION OF THE DEPOSIT CONTAINING MARINE SHELLS.
(X. Where the Shells occurred.)
PRINCES PIER
ESPLANADE
ALBERT HARBOUR
WEST HARBOUR
N
E
W
S
W. BLACKHALL STREET
UNION STREET
W. BURN STREET
HAMILTON STREET
CATHCART STREET TERMINUS
CALEDONIAN RAILWAY
REGENT STREET
REGENT STREET
LYNDOCH STREET
BANK STREET
SHAW STREET
INVERKIP STREET
NELSON STREET W.
NEWTON STREET
NEW RAILWAY TO GOUROCK
Shell X City
ROXBURGH STREET
SOUTH STREET

age. I examined this clay early in December last year, and found *Tellina calcaria* of frequent occurrence, the spines and plates of *Strongylocentrotus* (*Echinus*) *Dröbachiensis* and *Mytilus modiolus* and *edulis*. Very few species of shells, however, were observed. Mosses, seeds, and leaves of land plants were common. Marine Ostracoda were fairly numerous, but Foraminifera, though comparatively common, included but few species. It should be mentioned, however, that I had an opportunity of examining only a very small portion of the clay, so that there is every likelihood, had a considerable quantity of it been examined, that a much larger number of species would have been observed than those actually recorded in the appended list. All the shells and other calcareous remains were very fragile, so that it was difficult to secure anything like a perfect specimen; even such heavily-built shells as *Mytilus modiolus* being so much eroded that frequently little more than the epidermis was left.

The section, as I saw it in December, consisted of a thin superficial layer, next a thick bed of nearly pure sand, a sandy clay containing marine shells, a thick unstratified deposit of sandy Till, with numerous boulders, and, last, Calciferous sandstone of unknown thickness. The following measurements, which may be relied on as practically correct, were made for me by Mr. Patrick Grant, Clerk of Works, Greenock:—

Surface of ground at corner of Duncan and Roxburgh Streets, 72 feet 5 inches above sea-level.

(1) Thin superficial layer, from 9 inches to 1 foot thick.

(2) Surface of ground to top of shell-clay, 10 feet—nearly pure sand, excluding (1).

(3) Surface of ground to bottom of shell-clay, 14 feet (shell-clay, 4 feet thick).

(4) Surface of ground to top of rock, 30 feet (Till, underlying shell-clay, 16 feet).

It will be seen from these measurements that the bottom of the shell-clay is about 58½ feet, and the top 62½ feet, above sea-level, and therefore considerably higher than the Cartsdyke deposit.

The following is a list of remains observed in the small quantity of clay examined by me:—

PLANTÆ.

MUSCI.

A few species (not yet identified).

PHANEROGAMS.

Leaves, seeds, and fruits.

The seeds and fruits, of which there appears to be at least ten different kinds, are representatives of, among others, the following orders :—Caryophylleæ, Polygonaceæ, Cyperaceæ, Gramineæ.

[Since this paper was written I have submitted the seeds and fruits to Mr. Clement Reid, F.G.S. (of the Geological Survey), and he has been able to identify the following—*Potentilla tormentilla, Sibth.; Taraxacum officinale*, Wig.; *Thymus serpyllum* (?), L.; *Rumex*, sp.; *Atriplex patula*, L.; *Potamogeton*, sp.; *Carex dioica* (?), L.; *Anthoxanthum odoratum*, L.; and *Poa trivialis*, L. Two others have not yet been identified—June, 1888.]

Layers of vegetable matter were frequent all through the clay, and had a large quantity of it been examined, no doubt other plant remains would have been observed. No remains of Marine Algæ were noticed, but this was the more likely owing to the small quantity of clay examined, and partly to the bad state of preservation in which all the remains were, than to the real absence of marine vegetation.

FORAMINIFERA.

Reophax fusiformis, Will. Appeared scarce.
Polymorphina lactea, W. and J.
,, *compressa*, D'Orb.
Truncatulina lobatula, Walker. Frequent.
Polystomella striato-punctata, F. and M. Common.
Nonionina depressula, W. and J. Frequent.

ECHINODERMATA.

Echinus (*Strongylocentrotus*) *Dröbachiensis*, Müll. Parts of test, spines, etc., frequent.

OSTRACODA.

Cythere lutea, Müll.
,, *viridis*, Müll.
,, *pellucida*, Baird.
,, *porcellanea*, Brady.
,, *tuberculata*, G. O. Sars.
,, *concinna*, Jones.
,, *angulata*, G. O. Sars.
,, *villosa*, G. O. Sars.
Cytheridea papillosa, Bosquet.
Cytherura nigrescens, Baird.
,, *undata*, G. O. Sars.
,, *flavescens*, Brady.
Paradoxostoma variabile, Baird.

These were all more or less frequent, but not very well preserved.

DECAPODA.

Only part of a claw, possibly of a Hermit-crab, was observed.

CIRRIPEDIA.

Balanus crenatus, Brug. Scarce.

INSECTA.

Wingcases (Elytra) of two Beetles.

MOLLUSCA.

Mytilus edulis, Lin. Very common, especially young.
,, *modiolus*, F. and H. Frequent, but very much eroded and fragile.
Tellina calcaria, Chemn. Very common, but fragile.
Littorina obtusata, Lin. Frequent.
,, *rudis*, Maton. Frequent.

Although from the preceding list such characteristic species as *Pecten Islandicus* and *Astarte borealis* are absent, a more extended search might have brought to light one or both of them. But leaving these shells out of account altogether, the fact that *Tellina calcaria* was of common occurrence and perfect, though very fragile, points to the reasonable inference that the molluscs had lived and died where we found them—that they had not been washed into the clay from an older deposit—and thus affords fairly sufficient grounds for considering this clay to be of Post-pliocene age. [I have since learned that *Pecten Islandicus* has now been found near where the shells here recorded occurred—June, 1888.]

No. XXV.—Notes on the Jordanhill Coalfield.

By James S. M'Lennan.

[Read 10th November, 1887.]

This Coalfield is situated partly in the counties of Renfrew and Lanark, and comprises parts of the parishes of Renfrew and Govan. Its length from north to south is somewhat over a mile, and from east to west rather more than $1\frac{1}{2}$ miles, extending over an area of nearly 1,000 acres.

The dip of the strata in the eastern portion is to the north, and in the western towards the north-east.

In the centre of the field is a deposit of Brick clay, having an average thickness of 18 feet. It consists of two parts—the upper of a brownish-yellow colour, and unstratified, some 7 feet in thickness; and the lower of a blackish-blue colour, disposed in layers of various thicknesses and about 11 feet in depth. In these are

found the shelly clays or "Post-Tertiary Fossiliferous Beds" associated with the name of James Smith of Jordanhill, who, about forty years ago, directed his attention to these deposits; while, since his time, much additional knowledge has been gained concerning them from the researches of several members of our Society—notably Mr. David Robertson.

All over this district occurs beneath the surface a deposit of Boulder-clay. It thins out towards the east, and in the western portion of the field attains a thickness of 25 or 26 feet, its average depth being about 18 feet. The boulders which it encloses are mostly of local origin, or have been brought from a distance of less than 10 miles, 60 per cent. of them being derived from the white sandstone and shale, 30 per cent. from the traps of the Kilpatrick Hills, 10 per cent. from the slate and Silurian hills of Dumbarton and Argyll shires, and 1 per cent. from the granites of the Highlands.

Underneath the Boulder-clay lie several layers of shale, and in No. 8 pit a post of white sandstone some 12 feet thick was found. It is a coarse-grained stone, and somewhat hard in quality.

In the Greenlea pit, situated near the centre of the field, at a distance of 9 fathoms from the surface, occurs the first seam of coal —known as the "Wee Coal." It is of small extent, some 40 acres, and is now all wrought out. Its thickness is 22 inches, and it is a house coal of fair quality. It lies on a pavement of thin layers of sandstone known as "faiks."

The next coal seam found in the same pit is the "Main Coal," which lies at a depth of 16 fathoms below the "Wee Coal," or 25 fathoms from the surface. It has a thickness of 2 feet 2 inches in some parts of the field, but in the western portion it is $4\frac{1}{2}$ feet; and it crops out to the south near Skaterigg Farm, and a little to the west of Jordanhill mansion-house; also on the west side near the Joint Hospital. This same coal underlies the lands of Knightswood, Cloberhill, Drumchapel, Garscube, and Kelvinside. In the second last mentioned locality it is cut out by a large trap dyke running south-west and north-east, which is seen near the railway bridge over the Kelvin at Maryhill, and to the west at the old Netherton quarry. Beyond this it is found in all the pits westward, where it causes an upthrow of 30 fathoms, while in the Cloberhill pits still further to the west it is only 13 fathoms.

The seam is continuous, being free from "troubles," and its contents form a good kitchen coal. It has been wrought in this district for two hundred years, on the stoop-and-room system. Some of the "stoops" were 4 feet square, and were not left at regular intervals, nor of a uniform size. In that part of the field where these workings were discovered they had a depth of only 14 fathoms from the surface. The roads were narrow, about 6 feet wide, and were cut through the coal in the form of an arch, in a neat and workmanlike manner. In one of these old workings some wooden tools shod with iron, and wooden shovels, were found.

In the soft clay on the pavement prints of naked feet were seen, and it would seem that women were employed in carrying the coals on their backs to the pit mouth. In proof of this there is a story current in the district that on a Glasgow Fair Saturday, somewhere about the year 1690, three women were killed in a pit close to the North Lodge at Jordanhill by the falling-in of the "door heads," as they were termed.

When the workmen were engaged a few years ago in making a connection from the Greenlea pit to No. 14 pit, Skaterigg, they came upon some old workings in this coal which had been made about eighty years before. One of these workings was the level from which the "places" had been broken away. The regularity of the work was most marked—the places were driven 18 feet wide, with stoops 12 feet between them; and these working places extended 36 feet before through places were put in, thus leaving stoops 36 feet by 12 feet to support the roof. The coal here was 2 feet 2 inches in depth.

Descending some 12 fathoms lower, or 37 fathoms from the surface, we come upon the Old Blackband Ironstone. Previous to 1837 it was called by the name of the "drugget stane" from its striped appearance; and it had been gone through in four of the pits while they were sinking, but was not then known to be an ironstone. It is said that about that time a manager from the Carron Ironworks paid a visit to this district, and seeing pieces of the then-called "drugget stane" lying about, told the people that it was an excellent blackband ironstone. It lies in a basin in Jordanhill and Skaterigg, and covers about 200 acres in extent. In average thickness it is about $1\frac{1}{2}$ feet, and is persistent over its entire area. It was exhausted in 1867, after being wrought for 30 years. It was of excellent quality, 42 cwts. of the raw ironstone

making 1 ton of pig iron. The greater portion of the out-put was sent by the Canal to Dundyvan Ironworks and there smelted. In the neighbouring lands of Knightswood, Garscube, and Kelvinside a seam of coal takes the place of this blackband; and in the first-named locality it has been wrought as a steam coal.

Some $3\frac{1}{2}$ fathoms below the old blackband ironstone, or $41\frac{1}{2}$ fathoms from the surface, lies the Gas Coal, which covers as large an area as the blackband above it. It consists of 4 inches of free coal, 3 inches of "rad" or wild gas coal, and 9 inches of gas coal. In the western portion of the seam the free coal increases to 7 inches, and over one fourth of its entire extent it loses the gas coal and becomes free coal, while the wild gas coal grows in thickness. This coal is also found in the adjacent lands of Knightswood, Garscube, Cloberhill, and Drumchapel. In the first of these localities it was of excellent quality, and very easily obtained, as it lay at no great depth from the surface.

At a depth of 27 fathoms below the gas coal, or $68\frac{1}{2}$ fathoms from the surface, there is found the Blackband Ironstone, which was first discovered in the lands of Garscadden. Above this ironstone, in about 13 fathoms there are found 22 layers of clayband ironstone, varying from 2 inches to 14 inches in thickness; and 4 fathoms above these is a seam 9 inches thick composed of shells. In Jordanhill this blackband occupies some 60 acres of the same area as the gas coal; but with the exception of some 2 acres it has all been wrought out. It is found in Knightswood, and Garscadden, but not in Drumchapel. Its thickness is about 9 inches, with sandstone for its pavement, and "blaes" for its roof. It is of good quality, $2\frac{1}{5}$ tons of the raw material making 1 ton of iron. The name by which it is known in the district is the "brown stane." At Garscadden and Knightswood it is called the upper blackband ironstone.

The next to be noticed in this descending series is a layer of clayband ironstone, some 16 fathoms further down, or $84\frac{1}{2}$ fathoms from the surface, known as the "Garibaldi." It was so named, in honour of the great Italian hero, by the late Mr. A. M'Luckie, manager at Jordanhill, in 1860. It is made up of 6 inches of ironstone on the top, 2 feet 9 inches of "blaes" in the middle, and 8 inches of ironstone in the bottom. This clayband has a pretty wide range, being found all round by Maryhill, Kelvinside, and Knightswood. It is the best clayband ironstone in the district, 45 cwts. of the raw material making 1 ton of iron.

Some 3 fathoms above the Garibaldi seam occurs a thin seam of coal, which in Jordanhill is the equivalent of the Garscadden and Govan lower blackband ironstone.

In most of the pits to the west some 2 fathoms below the Garibaldi, or 86 fathoms down, a 14-inch seam of coal is met with, which as it goes to the south turns into 9 inches of ironstone, the rest being coal mixed with ironstone. It has not been much mined, being difficult to work. It is supposed to extend through some 50 acres of this coalfield, and it has been found and wrought at Cardonald, on the south side of the Clyde.

This seam, which was a coal, was so close to the Garibaldi in Garscadden that it was wrought along with it; but the working of it was stopped, as the "blaes" between the two layers of ironstone was over 5 feet in thickness, which thus made the workings far too high.

In Garscadden, 42 fathoms below the Garibaldi, or 126 fathoms from the surface in Jordanhill, the Johnstone Lower Clayband Ironstone is found. It underlies the Jordanhill and Knightswood coalfields, and though not mined in the former locality, it has been met with in several of the bores that have been put down there in different parts. In the latter district it was wrought in No. 10 pit, but was rather dangerous to work, owing to its having a bad roof. It is made up of 14 inches of ironstone on the top, 16 inches of "blaes" in the middle, and 18 inches of ironstone in the bottom.

Some 60 fathoms below that, or 186 fathoms from the surface, occurs the Hurlet Limestone and Coal, which have not as yet been reached in Jordanhill. Above this coal is the layer which contains the balls from which copperas is manufactured. The coal is 4 feet in thickness. Both it and the limestone have been worked at Garscadden, where, some 40 fathoms above, a seam of ironstone was found (supposed to be the same as the Nitshill Clayband), but so thin that it could not be wrought with profit, although said to be the best clayband ironstone in Scotland.

No. XXVI.—Note on the Composition of a Carbonaceous Sandstone.

By G. G. Henderson, M.A., B.Sc., *Assistant to the Professor of Chemistry, University of Glasgow.*

[Read 14th April, 1887.]

The peculiar Sandstone described in this note occurs at Tweed River Heads, New South Wales, but unfortunately I have been unable to obtain any information as to the character of the deposit or the nature of the associated strata; it would, however, appear, so far as can be judged from a hand specimen, to be of comparatively recent date. Some fragments of this sandstone were put into my hands by Mr. John Young, F.G.S., of the Hunterian Museum, who considered that it might possibly contain binoxide of manganese; the appearance of the stone afforded reasonable ground for this supposition. On examination, however, I found that this was not the case; the sandstone does not contain a trace of manganese, but its peculiar appearance led me to make a more exact investigation of its composition, and the hope that the results of this might be of some interest induced me to make this communication to the Society.

The sandstone is dark brown in colour, and small white granules are abundantly distributed through the binding material. It is soft, incoherent, and very friable—so much so that it is possible to rub it down to a coarse powder between the fingers. If the powder is examined under a low power of the microscope one sees numerous more or less rounded and sub-angular granules of quartz, many of which are almost perfectly transparent, and a quantity of a finely-divided brown amorphous substance. The quartz granules are evidently water-worn, and the amorphous matter has all the appearance of the product of sub-aqueous decay of vegetable matter, though I was unable to detect in it traces of vegetable structure. The sandstone has an average specific gravity of about 2·3, and when immersed in water for some time absorbs about one-tenth of its weight of that liquid, air bubbles being given off very abundantly. On ignition it gives off little or no smoke, crumbles away, and leaves an almost perfectly white residue. When heated before the blow-pipe with a little potassic nitrate it deflagrates. On exposure for some time to a temperature of 100° it loses

from 4 per cent. to 4·5 per cent. of hygroscopic water. The composition is fairly constant, as will be seen from the following analyses of samples from two different fragments, dried at 100°:—

	1.	2.
Insoluble Silica (sand), . . .	84·35	86·10
Carbonaceous matter, . . .	14·09	12·65
Soluble Silica, ...	0·47	0·34
Oxide of Iron and Alumina, . .	0·64	0·43
Lime, Magnesia, Carbondioxide, .	traces	traces
	99·55	99·52

A glance at the figures quoted above will show that the most remarkable feature is the large proportion of carbonaceous matter present. If the sandstone is roughly powdered and treated repeatedly with water, the lighter organic matter may be washed away from the heavier mineral substances. Obtained in this way it presents when dry the appearance of a fine dark-brown powder. It is insoluble in water, alcohol, ether, benzene, petroleum spirit, carbon disulphide, and oil of turpentine, but dissolves readily in solutions of alkalies and of alkaline carbonates. The solution is dark-brown and perfectly clear, though when concentrated so dark in colour as to seem opaque; on addition of a mineral acid the organic matter is precipitated in dark-brown flocks. The carbonaceous matter therefore contained in this sandstone is one of those bodies of rather indefinite composition which are classed together under the name of *humus acids*, and which are in many cases the result of the decomposition of vegetable matter. I have not yet had an opportunity of investigating the composition of the above-mentioned substance more closely, but hope to do so before long.

It would appear then from the above brief description that the black sandstone has the character not so much of a true carbonaceous sandstone as of a kind of very sandy peat, in which the vegetable matter has so far undergone decomposition as to lose all trace of its original structure.

No. XXVII.—Quartz as a Rock-forming Mineral.

By John Young, F.G.S., *V.P.*

[Read 9th December, 1886.]

In the few remarks which I have to bring before the Society this evening, I make no pretensions of offering any original observations on the mineral Quartz. What I have to state, for the information of the younger members, is only what has been made known during recent years in Geological Text-Books and in special papers, as to its modes of occurrence, the conditions under which it is found, and the important place it occupies, as one of the rock-forming minerals, it being estimated to form one fourth, perhaps, of the ponderable crust of the globe.

Quartz, a German miner's term for crystallized silica or rock crystal, is a mineral which is properly speaking colourless, but found of all tints when mixed with various metallic elements which are considered impurities, although sometimes they give it great beauty and interest, especially in those varieties known as gem-stones. In the scale of hardness of minerals, ranging from 1 to 10, quartz reaches 7, so that there are only 3 degrees between it and the diamond, which has a hardness of 10.

Quartz is an oxide of silicon, there being in 100 parts 53·33 of oxygen, and 46·67 of silicon, or silicium as it is sometimes termed, a dark brown powder, heavier than water, which, the base of silica, was first discovered by Berzelius in 1823, and is still only known to the scientific chemist. It is non-fusible before the blow-pipe and non-volatile. Silica or quartz possesses one or two interesting and valuable properties which may be stated here. When pure and colourless rock-crystal is heated to redness and quenched in water, it becomes opaque and friable, and if then reduced to powder, it presents one form of pure silica. In this state, when it is perfectly insoluble in water, if it be fused with three parts of carbonate of potash, it forms a glass which is soluble in water—and from such a solution, formerly called the liquor of flints, concentrated acids throw down the silica in the form of a gelatinous hydrate. If, however, the solution be diluted, and the acid gradually added, the alkali may be perfectly neutralized without any deposition of silica, which is therefore exhibited in a very soluble state; but if the solution be evaporated to dryness, the

silica remains as insoluble as before. This solubility of hydrated silica, which when dry is perfectly insoluble, may serve to explain the occasional occurrence of silica in mineral waters, and its deposition in various chalcedonic incrustations. Silica presents also another remarkable character. If we reverse the above proportions and fuse together a mixture of one part of carbonate of potash and three of powdered rock-crystal, or of calcined flint, a transparent and fusible compound insoluble in water, in fact a glass, is obtained.

This property of ready combination with other rock-forming elements may illustrate the abundance of silica in the rocks of the earth's crust. While existing in great purity by itself, yet if we take twenty-four of the other rock-forming minerals found in plutonic and volcanic rocks, we find that silica has combined with their elements to the extent of 68 per cent. in the felspars, and in gradually lessening quantities in the others until we come to chlorite, of which it represents only about 27 per cent. It also enters largely into the composition of many other rocks although not visible in its free or crystallized condition.

Should we search for the original sources of the silica or quartz found everywhere so abundantly in the rocky crust, and scattered as loose sand over the earth's surface, we find it in the heated waters of the molten magmas out of which the various plutonic and volcanic rocks have been formed. Quartz in these rocks presents this peculiar character, that while in certain conditions it is one of the most non-fusible and insoluble of minerals, in these magmas it is found to have been one of the very last of the elements to consolidate and crystallize. This property explains how quartz in its crystalline state, and as vein quartz, comes to enclose and envelop so many other mineral substances. Prof. Dana in his "Text-book of Mineralogy," when speaking of the conditions under which it occurs, says, "Quartz crystals also occur penetrated by various minerals, such as topaz, ruby-saphire, chrysoberyl, garnet and the different species of the hornblende and pyroxene groups, kyanite, zeolites, calcite and other carbonates, rutile, stibnite, hematite, gothite, magnetite, fluorite, gold, silver, anthracite, etc." And he then adds, "As quartz has been crystallized through the aid of hot waters or of steam in all ages down to the present, and is the most common ingredient of rocks, there is good reason why it should be found thus the enveloper of other crystals." Sir Charles Lyell in

his "Student's Manual," also remarks on this peculiarity in quartz, when speaking of the quartz of granite, and says, "As a general rule, quartz in a compact or amorphous state forms a vitreous mass serving as the base in which felspar and mica have crystallized; for although these minerals are much more fusible than silica, they have often imprinted their shapes upon the quartz.

"This fact, apparently so paradoxical, has given rise to much ingenious speculation. We should naturally have anticipated, that during cooling of the mass, the flinty portion would be the first to consolidate; and that the different varieties of felspar, as well as garnets and tourmalines, being more easily liquefied by heat, would be the last. Precisely the reverse has taken place in the passage of most granite aggregates from a fluid to a solid state, crystals of the more fusible minerals being found enveloped in hard, transparent, glassy quartz, which has often taken very faithful casts of each, so as to preserve even the microscopically minute striations on the surface of prisms of tourmaline. Various explanations of this phenomenon have been proposed by MM. de Beaumont, Fournet, and Durocher. They refer to M. Gaudin's experiments on the fusion of quartz, which show that silica as it cools has the property of remaining in a viscous state, whereas alumina (the earth of felspar) never does. This gelatinous flint is supposed to retain a considerable degree of plasticity long after the granitic mixture has reached a low temperature."

I referred at last meeting of the Society to the occurrence in vein quartz, and in the quartz of granite, of numerous fluid cavities, which indicated, in some instances at least, that the quartz in these specimens had cooled and consolidated under a pressure equal to that of 50,000 feet of overlying strata, and that this pressure prevented the escape upwards of the heated water or steam, now locked up in these fluid cavities. Also that the temperature of the rocks at this supposed depth would be equal to a dull red heat, visible in the dark. Sir Charles Lyell says that "water plays an important part in all volcanic eruptions, being so intimately mixed up with the materials of the lava that it is supposed to aid in giving mobility to the fluid mass, and that it is well known that steam escapes for months, sometimes for years, from the cavities of lava when it is cooling and consolidating." He indicates how this water comes to be present. "When rocks are melted at great depths water must be present for two reasons:

first, because rain water and sea water are always descending through fissured and porous rocks, and must at length find their way into the regions of subterranean heat; and secondly, because in a state of combination water enters largely into the composition of some of the most common minerals, especially those of the aluminous class." Also, "the existence of water under great pressure affords no argument against our attributing an excessively high temperature to the mass with which it is mixed up. Bunsen, indeed, imagines that in Iceland water attains a white heat at a very moderate depth."

Having stated thus much regarding some of the conditions under which quartz is believed to have consolidated in the granitic and metamorphic rocks, I shall now refer to some of the differences which exist between the crystalline quartz of granite, and that found in veins, when compared with that found in beds or strata —now termed quartzite. If we examine any clean-washed pure sand, it is seen to be almost wholly composed of grains of a crystalline silica, often highly rounded from long attrition in water, but in other instances more or less angular, and sometimes showing the primitive crystalline form. This sand tells us at once that it is derivative, and that its original source, however far back in geological time it can be traced, must be sought in the crystalline quartz of the igneous rocks, and in that of metamorphic strata.

All beds of quartzite, whatever be the age of the formation in which they occur, must first have been beds of loose sand, their subsequent consolidation being due to heat and pressure, and to the intensity of the regional metamorphism to which they have been subjected. In the arenaceous strata of the earth's crust we find every degree of consolidation, varying from the loose sand of our present beaches up through various stages of hardness, until we reach a rock of almost vitreous quartz, in which the original grains of silica can, in some instances, be barely detected, so much have they been fused together through the combined action of heat and pressure.

The earliest beds of sandstone in the oldest stratified rocks must originally have derived their grains of silica from the disintegration of rocks in which the quartz existed in a free crystalline condition. It may be of interest to remember that beds of sandstone may again and again be re-formed from the disintegrated material of older beds, and that without losing any of the

characteristics of the earlier deposits. Thus the sandstones of the Cambrian may have been formed out of those of the Laurentian rocks, those of the Silurian, Old Red Sandstone, and Carboniferous, each in their turn from the earlier sandstone formations, which again have each been exposed to denudation.

I remember that Professor Hull, while engaged on the work of the geological survey of this district, stated it to be his belief that the quartzite pebbles found in the sandstones of the Permian conglomerates of England were probably derived from the Scottish Old Red conglomerate, as no known rock in England corresponded to these pale reddish-brown quartzites, while the pebbles from the two formations seemed to be identical in colour and structure. In our own neighbourhood, on the south hill of Campsie, towards Strathblane, where thick-bedded white sandstones and conglomerates lie at the base of the limestone series, the pebbles of the conglomerates are almost exclusively composed of rolled vein quartz and quartzite, the latter having evidently been derived from beds of highly metamorphosed sandstone, probably of Cambrian or Lower Silurian age, while the vein quartz must have come from the fissures traversing these rocks. There is very little in the chemical composition of vein quartz rock to enable us to distinguish it from a highly metamorphosed sandstone or quartzite. In our purer sandstones, such as that of Craigleith, we find 98 per cent. of silica, and not much more is found in vein quartz. The points of difference lie then in the modes of occurrence.

As I stated before, all quartzites are only highly indurated sand beds, the siliceous grains of which were originally derived from igneous rocks, and vein quartz, in which the silica existed in a crystallized, or partly crystallized, condition. Vein quartz, and the quartz of granite and other igneous rocks, on the other hand, have been introduced into the cavities and fissures from silica held in solution, either in the original magma out of which these rocks were formed, or from highly heated waters which permeated them and filled the fissures wherever such existed. The silica, therefore, of quartzites, being a derivative material from older rocks, must always be more ancient than the strata of which it forms a component part, whilst that in the quartz of granite, and that found filling veins in the metamorphic rocks, is more recent in its formation than the strata which the granite erupts, or the vein quartz traverses.

In Jukes' "Manual of Geology," 1857, p. 147, par. 60, quartz rock or quartzite is described as "a compact, fine-grained, but distinctly granular rock, very hard, frequently brittle, and often so divided by joints as to split into small angular, but more or less cuboidal, fragments. When examined by a lens, it may be seen to be made of grains, which appear sometimes as if they had been slightly fused together at their edges or surfaces, and sometimes as if embedded in a purely siliceous cement. This cementation or semi-fusion of the grains shows at once that it is a sandstone which has been altered, and indurated by the action either of heat alone or of heat and water. It has been *baked* or *steam-boiled*." In a foot-note it is further stated, "The student must carefully distinguish between quartz rock or quartzite, as here described, and pure *vein quartz*, which occurs sometimes, as a white, compact, flint rock, in considerable mass. The "quartz-rock" so often spoken of in Australia is rarely if ever true quartz rock, but is commonly vein quartz—a deposition in a vein or fissure produced subsequently to the consolidation of the rocks it traverses, not an altered bed of sandstone, contemporaneous with the rocks in which it lies." He further states—"The continental geologists seem frequently to fall into the same mistake and confound two things essentially distinct. In a collection of European rocks purchased lately from Krantz of Bonn—among seven specimens of so-called quartzite—at least five were undoubtedly *vein quartz* and not *quartzite*."

The purity of crystalline quartz depends on its freedom from mixture with metallic elements, its normal state, as seen in many of the quartz crystals from the Brazils, being as pure as the clearest spring water. The purple tint of the amethyst is believed to be due to the metal manganese, and the smoky brown of the cairngorm to titanium. Iron, copper, nickel and other metals also colour other varieties, and beds of sandstone known to have been deposited as a nearly white sand, are often found stained by oxides of iron and hydrocarbon elements, subsequently introduced by percolation through the strata. The white opacity seen in many pure quartz crystals, and in vein quartz, is found to be mainly due to two causes, viz., minute microscopic fissures, and fluid cavities. I formerly mentioned that if a crystal of pure transparent quartz be heated to redness, and then plunged into water, it will be found to have become white and opaque, and its structure traversed by in-

numerable minute fissures—these being the chief cause of the opacity. Vein quartz since its formation has apparently often suffered from heating and cooling, it being generally very much fissured, and rendered still more opaque than would otherwise be the case by the multitude of minute cavities existing in its mass—due as previously stated to minute enclosures of fluid locked up in the quartz under enormous pressure whilst the silica was consolidating.

It might be asked, Why have not all quartz crystals these fluid cavities in their structure? The value of many Brazilian crystals, and of those used as gem-stones, is entirely due to the absence of these cavities, their presence depending entirely on the conditions of pressure and temperature at which the silica has crystallized. As I have said, silica is believed to have existed in the fluid state, in conjunction with water, at great depths in the earth's crust, and under great heat and pressure, and, after the associated minerals, with which it is now combined, were crystallized. I also mentioned that silica when combined with certain alkalies remains soluble in water after losing its heat, and that in this state, when the water is evaporated, it again becomes insoluble, and may be deposited in a crystalline or amorphous state according to conditions. I believe that these conditions explain the presence or absence in the quartz of fluid cavities, they being found in abundance in the quartz of granite, and in vein quartz, both of which are known to have consolidated under great heat and pressure. But with silica which has flowed upwards towards the surface, along with water from great depths, it would gradually lose its heat, and under the lessening pressure, all vapours would escape, and the silica would then crystallize without fluid cavities. According to the purity of the water of crystallization, and its freedom from metallic elements, so would be the purity and transparency of the quartz crystals formed. Such highly transparent crystals of quartz are generally found in druses or cavities of rocks which had previously cooled down to a normal temperature.

We find this same heat condition affecting the transparency of other minerals, amongst which I shall notice only the mineral calcite, under the beautiful form known as Iceland spar, which is calcite in its most transparent condition. It owes its transparency to the fact that the rocks in which it is found were never heated to

any great extent after the crystallization of the calcite took place. If a bit of the Iceland spar is heated, it becomes, like quartz, white and opaque, and does not regain its transparency.

Silica exists largely in many of the other strata of the earth's crust in a condition quite distinct from the ordinary crystalline quartz. In the flint bands and nodules of the chalk, and in other calcareous strata, it has been derived from the waters holding it in solution. This silica, in the form of flints, generally contains a small percentage of iron, clay and lime, which have become mixed with the sediments. The secretion of the silica of flints is so often associated with the growth and the decay of organic matter, especially that of sponges, that the late Dr. Bowerbank surmised the geological office of the sponges in creation to be to induce the deposition of siliceous matter held in solution in the ocean, just as the corals assist in the consolidation of the calcareous matter. When lime, iron, clay, or other matter increases in any flint bed, the rock passes from the normal condition of flint, and is then known as chert or hornstone.

Floatstone, or spongiform quartz, another form of silica, is chiefly composed of the siliceous coverings of diatoms and other protozoan organisms. The analyses of some beds give 85·9 of silica, 0·7 of alumina, 9·1 carb. of lime, and 3·3 of water. Many of the beds are several feet thick, and are chiefly of lacustrine or fresh-water origin.

Igneous rocks in which silica abounds, either in a crystallized or combined state, are said to belong to the acid group. Those in which the silica is less, and seldom in a crystallized condition, are termed the basic group, from being composed of heavier mineral elements. Dr. Page, in explanation of the term, "acid group," as applied to the siliceous form of igneous rocks, says, "Although silica has none of the ordinary or more obvious acid properties, yet as it combines in definite proportion with many salifiable bases, and expels carbonic acid when fused with the carbonated alkalies, it is very commonly termed silicic acid, and its various compounds have been denominated silicates."

Very much more might be said regarding the many varied and interesting conditions in which silica or quartz presents itself to the mineralogist and geologist, as well as of its many industrial uses, about which much interesting information will be found in Dr. Page's "Economic Geology." In this work will be found

noted the various building-stones in which quartz forms from a half to nearly the whole of the material, as in the granites, syenites, porphyries, felstones, greenstones, basalts, slates, schists, quartzites, and sandstones. For mechanical industrial purposes, we have quartz or silica, as the more important element in millstones, grindstones and cutting wheels, crushing and pulping wheels, polishing and cutting materials, whetstones, hones and burnishers. In the clays used for pottery and other industrial purposes silica is found, varying from 50 to 70 per cent. and upwards, and as much as 90 per cent., it is stated, is not at all incompatible with the formation of excellent bricks. In the gemstones of the silica group proper we have the rock-crystal, amethyst, cairngorm, chalcedony, agate, onyx, carnelian, jasper, opal, etc., in all their varieties. And lastly, in the sands we vitrify, we find that silica lies at the foundation of all the great industries of glass-making, where ground flints and sands of various degrees of purity are used. For very pure glass crushed quartz or well-washed silver sand, free of iron and other mineral impurities, has to be employed, but for ordinary bottle-glass sea-sand is often preferred, as the lime, clay, and other admixtures it contains, increase its fusibility.

Dr. Page, remarking on the interest and value of the mineral and metallic products used in the industries of glass-making, says, "Thus one of the most beautiful and useful fabrics ever invented by man depends at once for its composition, its colour, transparency and other qualities, upon the mineral and metallic products of the rocky crust; and whether we regard the amount or variety produced—the opaque bottle, the transparent window pane, the shining mirror, the sparkling crystal, the coloured ornament, or the pellucid lens of the optician—there is no mastery of art over the crude materials of nature so decided and triumphant as that of the glass manufacturer."

No. XXVIII.—Notes on the Heads of Ayr. By Walter Burns.

[Read 10th May, 1888.]

The cliffs known as "The Heads of Ayr" are about three miles south-west of the town of Ayr. The sections which I am about to describe are at Bourhill and Greenan Castle, both on the coast line, and the strata lying between these two points, the distance being about one mile. Bourhill, the highest point, is about 100 feet above sea-level. It is a mass of volcanic ash and agglomerate of a dark-green colour, and belongs to the Calciferous sandstone series. It appears to have been erupted subsequent to the deposition and solidification of the cement limestones, of which fragments are firmly embedded in the ash. It has also the appearance of bedding. If so, the eruptions of ash must have followed one another at very short intervals, as there appears to be no foreign matter between them. In the coast section are to be seen the same contemporaneous trap tuffs interbedded with the cement limestones.

The section on which Greenan Castle is built is of similar composition. As regards the dolerite dykes in this locality, there are six marked in the Geological Survey map, one of which, well exposed to view, and known as the "Deil's Dyke," can be traced more than a mile seaward at low water. They are apparently all of Miocene age.

The next group is the cement limestone series, also belonging to the Calciferous sandstones, which is well exposed between high and low water mark from Greenan to Bourhill. In the explanatory *Memoir* to accompany the Geological Survey map it is stated that "the series consists of numerous alternations of grey, green, and blue shales, argillaceous marls, white or grey sandstones, and ferruginous limestones or cement-stones. Some of the strata abound in organic remains, as cyprid cases, fish scales, and plants." The lie of the beds is at a very low angle, and the general dip is north-east. At Bourhill it is south-west, dipping under the hill; and a little to the S.E. the dip is north-west. The cause of these changes is, I think, due to the great amount of volcanic ash, of which Bourhill is composed, resting upon these beds. If they are continuous, and I observed no breaks, supposing the lowest to be at Bourhill and the highest at Greenan Castle, the depth would

appear to be very great. The Geological Survey *Memoir* states that "a bore was put down through 330 feet without reaching the bottom at M'Nairston, five or six miles south-east of Ayr," so that in that locality also they appear to be of great thickness.

A most interesting section is the drift bed, which flanks the north-east side of Bourhill. It is a mere fragment, the length being about 30 yards and the depth at the thickest part not more than one or two feet, which thins away towards the east until it disappears. In a few remarks which I formerly made at a meeting of the Society on the occurrence of Chalk flints in this drift bed, and which are printed in the *Transactions* (vol. vi., p. 283), I am represented as having said that this bed was about 20 feet above high-water mark. What I really said, or ought to have said, was that the surface of the bank was about 20 feet at the highest point, and that the drift was from 15 to 16 feet above high-water mark. Since that time I have again gone over the ground, and I have found flints above the "Deil's Dyke," where I had a better opportunity of taking the correct height, which is between 9 and 10 feet. Remembering a statement by Mr. John Young, regarding the occurrence of flint nodules on this coast, that any one having an opportunity should be sure to make a search for flints in these beds, I began a careful inspection at the east end, but I had nearly reached the west end before I found one, and this I broke in two to find that it was a piece of pure chalk flint. I continued the search until ultimately I discovered about 20 nodules. As, so far as I am aware, there neither are, nor have been, flint-bearing strata in this locality, the questions arise—From what district did these flint nodules come, and by what agency were they transported? The same questions come up regarding the pebbles with which the flints are now associated, and which appear to be rolled fragments of rocks, probably belonging to the North-west of Scotland.

Looking from the Heads of Ayr across the Firth of Clyde towards Campbeltown, the thought presents itself that this channel may have been filled with glacier ice, and the more I have thought over it the more have I become convinced that such has been the case. Prof. A. C. Ramsay, in his "Physical Geology and Geography of Great Britain," p. 382, writes :—"Another part of the great glacier ice passed west across the Hebrides, and southerly into the Firth of Clyde, where, passing over Bute and

smothering and smoothing those large mamillations, the Cumbraes, it was reinforced by the snows of Arran and buried that craggy ocean pyramid, Ailsa Craig." I believe that it was probably during the Great Ice Age that these rock specimens with their kindred boulders, seen lying on the shore, were deposited on the sea bottom, or what was formerly the sea bottom. I suppose it is now generally agreed that the Great Ice Age came on by slow degrees, and that it declined in the same manner ; also that the land was submerged from one to two thousand feet. The length of time required Mr. Pengelly sets down, if I remember aright, at some 200,000 years. If so, the time between the deposition of the Scottish pebbles and the laying down of the Irish flints would appear to be many thousands of years. Probably the means of conveyance of the flints from the Irish to the Ayrshire coast was by floating ice. Let us suppose that a time had come when the channel was again comparatively free of ice, and that the land had risen to within 20 or 40 feet of its present level. The higher hills were probably still capped with snow, the glens filled with retiring glaciers, and during winter the shore was icebound. Some of us may have often observed in ponds in old quarries that the water, during a severe frost, is converted into ice. When the thaw comes, and the ice is broken up into fragments, the ice-foot is seen to be firmly packed with stones. In a similar way we should expect it to happen in shallow reaches on the sea coast, where the ice would reach the bottom and take up the pebbles into its foot. When the thaw came storms and tidal waves would break it up into masses, floating it hither and thither seaward. With a south-west wind blowing many of these would probably be floated from the North of Ireland right on to the Ayrshire coast, and there, melting away, the flints would be dropped on the sea bottom above the Boulder-clay. By some such means they may have been carried here and deposited. It will be observed that these flint nodules are of very small size, and there may be some difficulty in accounting for this, but one simple explanation is the long time they may have been subjected to rolling, and that the smallest were carried furthest.

Under what conditions was the bed of marine drift which contains the flints and rolled pebbles formed? The land was then probably from 20 to 40 feet below its present level, but it was still continuing to rise slowly, thus bringing the sea bottom more within the action of the tide, which would then wash and denude

away the boulder drift, and as the sea gradually retired through the rising of the land it would heap up the gravel on the shore, and this action would continue until the land became stationary. In some such way, I think, this drift bed was probably formed, and the flints and pebbles re-deposited together at the same time. The water line would then be not less than from three to four miles further seaward than it now is, so that the site on which the town of Ayr is built must have been about that distance inland. It may also have been that during the last rising of the land, and after it became stationary, the mounds of blown sand, so abundant from Prestwick northwards along the ocast, were heaped up.

As the life of man is far too short for him to be able to observe great geological changes, he has therefore to be guided in a great measure by circumstantial evidence, and we have, I think, some such evidence at Greenan Castle. Any one now looking at it would never believe that this old fortress was originally built so near the edge of the cliff as it now stands, for it is impossible to walk round the outer wall, while the base of the cliff is cut inwards 4 or 5 feet further than its upper edge. As proof of its once farther extension, we are told that within the last 100 years a carriage could have been driven round the castle, but in a comparatively few more years at the present rate of denudation, we shall not be able to mark the spot where Greenan Castle stood.

The next point we may notice is how the bed of drift along the shore has been reduced. As soon as the land became stationary, the work of denudation would begin, and the sea having a more permanent face before it would begin to remove that which for so long a time it had been helping to build up. Every time I visit the Heads of Ayr I observe a change. Perhaps a piece of rock loosened, which, when I next look for it, may be broken up and washed away. The same thing happens with sand and gravel mounds. I was much struck at the state of matters three years ago when visiting this locality, especially the ground at the north-east side of Bourhill. On walking up to the former bed of drift, I found that instead of having to clamber up a height of several feet, it was not two feet above the level of the ground on which I stood, which I found to be some 6 or 7 feet higher than on my previous visit. Of the boulders, large and small, which were formerly to be seen by the thousand, there was now not one visible.

A great part of the talus of the hill had apparently been washed away, and it appeared to be this material on which I was now standing. Going up to a cottage near the shore, I said to a woman who lived there, "You surely have had a severe storm here lately." "Yes," she replied, "it was last January, and the water was up as high as the door step." Then I recollected that a severe storm had at that time broken over the west coast, vessels being wrecked, and lives lost. A considerable portion of the sea-wall of the esplanade at Ayr was broken down, and the dyke of the Low Green was, if I remember rightly, entirely swept away.

On a later visit to Bourhill I noticed that the whole of the debris here mentioned had been again washed away, and that the boulders were exposed as formerly. I think it would be well if the members of the Society who have opportunity would take note of any such changes they may observe along our western coasts and report upon them. A series of such observations would be of great interest and value.

No. XXVIII.—Notes on the Scottish Carboniferous Genera of the Molluscan Family Anatinidæ. By John Young, F.G.S.

[Read 8th December, 1887.]

In the following notes, I intend to point out shortly some of the characters which distinguish the genera of the molluscan family Anatinidæ, found in our Carboniferous strata. As you are all aware, the various groups of organisms—plants and animals, fossil and recent—have been classified under the terms, kingdom, class, order, family, genus, and species, as here given, the grouping being determined from the points of external resemblance and internal structure in the organisms themselves. This arrangement enables botanists and zoologists to understand all the more clearly the various positions and relationships in both the vegetable and animal kingdoms. According to Woodward's "Manual of the Mollusca," the Anatinidæ belong to the Conchifera, the 5th class and 9th order of the Mollusca, and form the 19th family of its class. The Conchifera of Lamarck are likewise known as the Lamellibranchiata, which are further divided into two groups, viz., the Monomyaria, and Dimyaria, according to the number

of muscular scars inside the shell, the Anatinidæ being placed with the latter.

The family of the Anatinidæ, or Lantern shells as they have been termed from their thinness and translucency, embraces several fossil genera found in strata belonging to the palæozoic, mesozoic, and cainozoic periods, and the family still continues to be represented in recent seas by several genera and species. So far as yet determined, there seem to have been no representatives of the true *Anatina* in Scottish Carboniferous deposits. Prof. M'Coy has, however, described two species from the Carboniferous limestone of Ireland, but Prof. Morris, in his "Catalogue of British Fossils," only admits them doubtfully into his list of the fossil *Anatina*. It is always very difficult with fossil species of the Conchifera to determine correctly the true relationship of the various genera to each other. This arises from our not being able in most cases to determine what are the internal characters on the interiors of the shells, and upon which their family and generic relationships often depend.

In Woodward's "Manual," the characters of the shells in the family Anatinidæ are briefly described as follows:—Shell often inequivalve, thin; interior nacreous; surface granular; ligament external, thin; cartilage internal, placed in corresponding pits, and furnished with a free ossicle; muscular impressions faint, the anterior elongated; pallial line usually sinuated." It is further stated, as in the case of *Pholadomya* and its fossil allies, that "the external surface of these shells is often rough with large calcareous cells, sometimes ranged in lines, and covered by the epidermis, the outer layer consists of polygonal cells, more or less sharply defined."

The following are the Scottish Carboniferous genera at present allocated with the Anatinidæ: *Myacites*, Brown, 1830; *Leptodomus*, M'Coy, 1844; *Sanguinolites*, M'Coy, 1844; *Edmondia*, de Koninck, 1844; and *Cardiomorpha*, de Koninck, 1847. These genera are all essentially marine, being found along with other marine shells in both the lower and upper limestone series, but as a rule they are more often found in the argillaceous beds of the limestone strata than in the limestones themselves. This mode of occurrence is also characteristic of nearly all the other genera of the Scottish lamellibranch mollusca, and has already been noted, when remarks were made on the group, in the "Catalogue of Western Scottish Fossils, 1876, p. 50." *Myacites*, the oldest of

the Carboniferous genera, is represented in our strata by only one species, *M.* (*Hiatella*) *sulcata*, Flem. The genus *Allorisma* was subsequently formed for this and one or two allied species by Prof. King, in his "Monograph of Permian Fossils," but has not been generally accepted. Prof. M'Coy placed *Myacites* with *Sanguinolites*, but Prof. Morris has retained it as it was, in his "Catalogue of British Fossils," and as such the shell is best known to us. It has been found in several localities in the West of Scotland, chiefly in the lower limestone series, but as far as yet discovered, it seems to be nowhere common. When well preserved, the shell is seen to be very thin, a characteristic of the family, and some examples show the radiating lines of minute raised tubercles which give the surface of the shell its granulated appearance. Closely allied to *Myacites*, and sometimes placed with it is the genus *Leptodomus*, already mentioned. Woodward, in his "Manual," shortly defines its characters as, "Shell thin, ventricose, concentrically furrowed in front; escutcheon long and flat." M'Coy's description of the genus is much longer, but need not here be quoted, beyond the statement that "these fossils seem almost identical in form and thinness of the shell with *Myacites*," but he shows that it differs from it and the genus *Sanguinolites* in several external characters. M'Coy, in his "Palæozoic Fossils," describes seven species of *Leptodomus*, six from Silurian, and one, *L. costellatus*, from Carboniferous strata.

The type specimen figured by M'Coy is from Craigie, near Kilmarnock, where, he states, it is "common in the Carboniferous shales." He also records it "from Carboniferous shales near Glasgow," and "in the shale beds at Lowick, Northumberland." Since the period (1855) when M'Coy's description appeared, this shell has been found moderately common in several other localities in Western Scotland, but nowhere so abundant, of so large size, and in such fine preservation, as in the shale beds of the limestone series cut through this last summer at Girdie, on the new line of railway between Barrmill and Kilbirnie, Ayrshire. For a knowledge of this interesting locality for the shell under notice, we are indebted to our esteemed corresponding member, Mr. Robert Craig, Langside, Beith, who has diligently collected the fossils in these shale beds, and who last summer guided a joint excursion of the Edinburgh and Glasgow Geological Societies to the locality. Mr. Craig has been collecting notes on the strata

exposed along this new line of railway for some time, and I hope, when these are completed, that he will present the Society with an account of what he has observed, with a list of the fossils.

I may here mention that M'Coy's type specimen of *L. costellatus*, from Craigie, is given as one inch five lines in length, but those from the Beith railway cutting that I have measured are two inches one line in length, and proportionally as large in every other direction. They were found in nearly every instance with their valves united, and very seldom much crushed. The evidence from this and the other localities where this shell has been found is that this species burrowed in the mud; hence after death their fragile shells would remain in the sediments, and so not be nearly so liable to be broken or scattered about by the sea waves. The state of preservation of the shells in this locality not only shows that the interior layer was nacreous, but that the middle layer has a minute acicular structure, and the outer layer a coarse structure with large calcareous cells. These characters are all well seen in sections of the shell that I have prepared for examination under the microscope. In other localities the shell has generally not been so well preserved, being in some instances pyritized.

The genera *Sanguinolites*, M'Coy, and *Edmondia*, de Koninck, seem both to have been established in the same year (1844), and are held by some palæontologists to be so closely related in their characters as to be identical. Woodward in his "Manual" unites *Sanguinolites* with *Edmondia*, and gives the following as the generic characters:—"Shell oblong, equivalve, thin, concentrically striated, close; umbones, anterior; ligamental groves, narrow, external; hinge-line thin, edentulous, furnished with large oblique cartilage plates, placed beneath the umbones, and leaving space for an ossicle? pallial line simple?"

At present both the genera are admitted into the lists of Carboniferous fossils, the species with the longer form of shell being placed with *Sanguinolites*, and the shorter forms with *Edmondia*. In the "Catalogue of Western Scottish Fossils" no less than nine species of *Sanguinolites* and nine species of *Edmondia* are noted from various localities and collections, but I am very much inclined to think that several of the species there given are due to faulty determinations, and that we have not more than half the number stated. I also now know that one or two of the forms hitherto placed with the above genera do not belong to the family of the

Anatinidæ, and will have to be placed elsewhere amongst the Conchifera.

The species of *Sanguinolites* and *Edmondia* found in Scottish Carboniferous strata range from the marine beds of the lower limestone series into those of the upper limestone, but are chiefly found in the shale beds. Their habit of life seems to have been very much akin to that mentioned in connection with *Leptodomus*, their shells also being generally found with the valves united, indicating the conditions under which they lived. In illustration of this point, I may mention that in the thin band of impure cement limestone found at Bishopbriggs quarries, north of Glasgow, the fine specimens of *Edmondia sulcata*, Phill., there obtained were generally found with their valves united, standing in their natural vertical, burrowing position in the sediment. In this same stratum the shells of *Pinna flabelliformis*, Mart., were also found standing erect, and with their valves united, showing that the palæozoic species were, like their modern representatives, burrowers in the sediments where they lived.

The next form to be noted is the genus *Cardiomorpha*, de Koninck. Woodward, in his "Manual," admits it somewhat doubtfully amongst the Anatinidæ, and briefly describes its character as follows :—"Shell Isocardia-shaped, smooth or concentrically furrowed, umbones prominent, hinge edentulous; hinge-margin with a narrow ligamental furrow, and an obscure internal cartilage groove." M'Coy, "Palæozoic Fossils," p. 509, also remarks on the genus, stating that the shells of *Cardiomorpha* are very thin, resembling the recent *Isocardia* exactly in form, but perfectly distinguished by want of teeth; which character, and the inflection of the cardinal margin, approximate the genus to *Leptodomus*, M'Coy, from which they differ by their large inrolled beaks and closed margins, without byssal furrow, etc. From the extreme thinness of the shell the muscular and pallial scars are rarely visible.

In the "Catalogue of Western Scottish Fossils" seven species of *Cardiomorpha* are noted from the Carboniferous limestone strata. Several of these are very rare, and one or two appear to be doubtful identifications. The most common species, although still a rare shell, is *C. oblonga*, Sow., found in both the lower and upper limestone series in several localities. None of the species of the genus found in our beds seem to have reached the size of those obtained from the English and Irish limestone strata. Those I exhibit are

from the Robroyston limestone series, north of Glasgow, and are the largest and finest I have yet obtained.

I have only one other Carboniferous genus to notice, one which has provisionally found a place amongst the Anatinidæ, and of which two species are stated to have been found in Scottish Carboniferous strata. This is *Sedgwickia*, M'Coy. Woodward in his "Manual" makes it, however, to be only a sub-genus of *Myacites*. The shells of the species of *Sedgwickia*, are, in general, of small size. M'Coy in describing their generic characters, says, "Shells equivalved, or nearly so, inequilateral; shell very thin, inflated; dorsal and ventral margins subparallel; anterior half of each valve marked with strong, transverse ridges; posterior half smooth; beaks moderate; anterior side very short, round; posterior side broad, lengthened, subtruncate." He further says, "These beautiful shells are remarkable for having the anterior half of their valves marked with strong, transverse ridges, and the posterior half perfectly smooth." I may here state, that the genus *Sedgwickia*, so far as known to me, has not yet been recorded from the Carboniferous strata of western Scotland, and I only notice it here, because Mr. Robert Etheridge, sen., in his Presidential Address to the Geological Society of London, *Quarterly Journal*, vol. xxxvii., p. 219 (1881), gives a table of "18 of the chief Dimyarian genera" found in England, Scotland and Ireland, and in that table Scotland is credited with 2 species of *Sedgwickia*, and Ireland with 7 species, none being found in English Carboniferous strata. It is not stated in what district of Scotland these specimens were obtained, nor from what horizon of strata. If the genus has been correctly identified the specimens are probably from some of the eastern districts, as it is not recorded in the "Catalogue of Western Scottish Fossils." Neither can I find it amongst the numerous lists of fossils given by the Geological Survey in their *Memoirs* explanatory of the geological maps of the western coalfields.

In bringing these remarks to a conclusion, I have only further to state, that a great deal of investigation still requires to be made into the group of shells forming the Conchifera, or lamellibranchiate mollusca, of the Carboniferous period, before we can arrive either at their numbers or true relationship to each other. In the address of Mr. Etheridge already referred to, he states, p. 217, that the united British Carboniferous Lamellibranchiata, forming the

two divisions Monomyaria and Dimyaria, number 54 genera and 424 species. I am quite certain that in the hands of any specialist these figures would be very much reduced, especially as regards the number of species in several of the genera. The case here is very much the same as that which the late Dr. Davidson found amongst the Carboniferous Brachiopoda when he took up that group for investigation, as already recorded in a former paper to the Society by myself ("Notes on the Carboniferous Brachiopoda of Scotland," *Transactions*, vol. viii., p. 144). It is there stated that Dr. Davidson found that then no less than 260 so-termed species had been named and recorded by various palæontologists from the Carboniferous strata of Britain and Ireland: but that he, after labouring amongst the group for a long series of years, and assembling specimens from all the collections to which access could be obtained, decided, after a most searching investigation, he could not admit more than about 100 of these into his list, and that amongst these there were still some doubtful forms which were probably only varieties.

If such has been found to be the case with the Carboniferous Brachiopoda, which possess better marked internal and external characters than many of the Carboniferous Conchifera, we may, as already stated, expect a great reduction of the number of so-termed species of this group when they come to be carefully examined. As a case in point, I may mention that Mr. Etheridge, in his "Address" quoted above, states that 150 species of the genus *Aviculopecten* are found in the Carboniferous strata of Great Britain and Ireland, including 50 from Scotland. I have good reasons for believing that this is far beyond the number of species in the genus. I also know that, in several instances, species in this genus have been founded on the differences existing in the ornamentation of the opposite valves of the same shell, these being generally in a disunited state when found. Differences in the conditions of growth over the old sea bottom, and in the nature of the sediments in various localities, as well as the existing state of preservation of the shells themselves, have, either singly or combined, produced variations in the same species, which in the hands of different palæontologists have caused their erection into new species. What I have here stated regarding *Aviculopecten* might also be urged against many of the other genera of the fossil Conchifera. There seems in the past to have been too great a desire to make new species, and we wait for the

time when some specialist will do for the Lamellibranchiata what the late Dr. Davidson so ably did for the Brachiopoda, bringing the group out of confusion both as to genera and species, and thereby enabling students of the mollusca to form a fuller and clearer conception of an interesting class of organisms, which formerly, no doubt, played an important part in the world's life-history.

No. XXX.—The Redemption of Sandstone Quarries. By James Bennie, of the Geological Survey of Scotland.

[Read 31st May, 1888.]

I shall perhaps most fitly introduce the subject of this paper with a reminiscence. At an early time in my pursuit of fossils, I was attracted to the shale heaps in limestone quarries as giving the most congenial opportunities for collecting. This was due to the fact that neither crowbar, pickaxe, nor shovel, nor even hammer was required to resurrectionize the remains of the long-past dead that I coveted, this having been already done by the hands of the quarrymen, helped by the disintegrating influences of the weather. All that I had to do was simply to kneel down on the weathered shale heaps, and lift the fossils as easily as is done in gathering shells from the sands on the seashore. For many years, I therefore haunted all the shale-bearing quarries within an easy walk or railway ride from Glasgow. The yield of fossils was great at first, especially in the shale heaps I was the first to discover and search, and for a long period I had full occupation for all my holidays. By-and-bye, however, as the time rolled on, the field became exhausted, first of the rarer fossils and then of the more common species, till at length the crop did not repay the trouble of gathering, and for a whole year the only outlet I could get for my leisure time was to ramble in search of the picturesque and the beautiful in scenery. But I well remember how little I was pleased with the change, and how I sighed for new ground which had not yet been searched by fossil-hunters like myself. Fortunately, this interregnum lasted only for a short time, and by a new revelation of hitherto unsuspected ways and means of getting

undreamed-of fossils in the old shale heaps, my interest in them was revived and intensified. This was caused by learning, chiefly from Mr. John Young, that by taking weathered shale exhausted of its larger fossils, and washing it, thousands of smaller organisms could be found in the residuum. These minute fossils being new to me by sight, and some even by name and nature, all the quarries which contained shale which could be washed, were re-visited with increased zest and greater frequency, as there was no chance for many long years of the shale being exhausted of their minuter forms; and Orchard, Robroyston, Blantyre, and Kilbride became again the favourite goals of my geological rambles.

What happened many years ago with shale-yielding quarries has lately taken place in my experience with sandstone quarries. In the course of some researches which were made in quest of beds containing spores, I have found that many old sandstone quarries, from which nothing has ever been got since they ceased to be worked, have yet in their waste heaps materials which have yielded fossils previously unknown in such places, and which have opened up to the mind scenes and incidents unthought-of in such connections, thereby imparting a new interest to them which amounts to their complete redemption from the barrenness to which they had been consigned. Thinking that the members of the Geological Society of Glasgow, who, like the ancient Athenians, have always been famous for seeking after new things, might take an interest in what I have to say upon this subject, I have brought this paper before them to-night.

In the paper "On the occurrence of spores in the Carboniferous Formation of Scotland" (*Proc. Roy. Phys. Soc. Edin.*, vol. ix., p. 82), there is an allusion to spores having been found in Hailes quarry, in the partings of carbonaceous matter in certain fakey layers in the sandstone, and the suggestion is made that all the black streaks and blacker laminæ which so distinctively characterize this sandstone were probably made up, chiefly, if not wholly, of spores, sacs, and fragments of wood, which had been floated by streams, or wafted by winds, into the lake in which the 200 feet of rock were formed. Also that among these vegetable waifs of land or water were frequently found fragmentary remains of animals, such as scorpions and eurypterids, which had, of course, been carried into the lake from the land by similar agencies, and deposited like the spores and sacs. In the same

paper, in the list of localities where spores were found, Joppa quarry was noted as having spores in black fakes in its eastern face. Since the paper was published I have pursued the same line of research, and have found many instances where black fakes have yielded in great abundance the same objects as in Hailes. Perhaps, however, the best examples are those of Kingscavel Quarry, near Linlithgow, and South Coltpark, near Bishopbriggs, both of which are notable instances of how "the Redemption of Sandstone Quarries" has been effected by the search for spores, and how they have been thereby saved from being given over finally to the "abomination of desolation."

The workings at Kingscavel quarry, from which the stones of the palaces and towers of Linlithgow, the "ancient Windsor of Scotland" as Lord Rosebery called it, were derived, having been discontinued for 15 or 20 years, there was no hope of any fossils being got from the beds, and the fossil-seeker going into it, and seeing only waste heaps of broken sandstone or bings of useless fakes, might in his chagrin curse it with the curse of the barren fig tree, and turn from it with contempt and disgust, as I myself would, a few years ago, have done with emphasis. But having learned from Hailes that more was to be had in fakes than met the uninformed eye, I was greatly delighted on my first visit to Kingscavel two years ago (1886), to see a great depth of rock composed of black fakes, and still more pleased to find that much of these fakes had been lifted and stored up in the quarry, as if purposely for my special benefit, when circumstances had taught me their value, and how to put them to palæontological use.

The section in Kingscavel is, in descending order, as follows :—12 feet or so of blue earthy shale with ironstone ribs and nodules, 12 feet or so of amorphous sandstone, 2 feet of soft shale with 8 inches of good coal, 30 feet of sandstone, and beneath it several feet of black and white fakes. In the undersoil, beneath the 8 inches of coal, spores, scorpions' skin, and the usual vegetable *debris* were found. Through the bottom beds of black fakes a tunnel had been driven for a quarter of a mile or so, and a tram rail laid to the canal bank, perhaps half a mile. The fakes have been piled up or built into walls to support the heaps of *debris*, and keep them from falling down and blocking the cart-ways from the working face to the tunnel. These fakes when quarried had been firm and compact, and therefore fit for building into these

walls, but the weather had rendered them soft and loose; they could therefore be easily cut into with my trowel and crushed by the hand in water, and thereby be made to disintegrate into their individual parts, so that their characters could be determined with ease and precision. But this disintegration was not universal, as much of the vegetable *débris* having fermented in the process of mineralization had been converted into bitumen, which, acting as a cement, prevented most of the spores from being individualized. Again, the spores having been much compressed, they became thin and mere scale-like films, all the soft substance having been squeezed out of them, with only the skin left behind. Again, they were so often fretted and rubbed by the grains of sand upon and among which they lay, that they were not so robust in body or even so smooth-skinned as those which are embedded in soft clay or shale. Still many escaped unhurt, and are so perfect in appearance as to enable us to realize them as they were in life, or early after death. Besides the sacs and spores were many bits of scorpion and eurypterid skin, quite distinguishable as such by the ornamentation embossed or inserted into their substance.

On my visits it was very pleasant to sit and lunch in Kingseavel; the high walls of rock on every side made it "lown," while its width allowed the sun to light it up clearly or brilliantly. Some four or five years previously it had been planted all over with young firs and other trees, which having grown a foot or two high looked very beautiful, the dark-leaved spruce or Scotch firs contrasting finely with the light yellow green of the larch and beech. Another circumstance which added much to the pleasure I had in searching the washed results of my gatherings was due to the fact that many fragments of recent insects and flies were mixed with the fakes, and turned up frequently to the eye, as I scanned the material scattered on the slate to be searched. Every now and then a spore or a thistle seed, a sac or a withered leaf, a bit of scorpion skin or the wing case of a beetle, a bit of eurypterid skin or the head, or eye, or wing of a fly, or portion of a spider appeared. The past life of the Carboniferous time thus intermingled with that of the present suggested many thoughts and fancies which made the search a pleasure and a delight. The cause of this interpenetration of the present into the past was doubtless due to the fact that the wall of fakes stood in the quarry facing the sun, and the flies and insects which love to bask

in its rays frequented these nooks and crannies in preference to the more shady corners. The spiders and other predatory creatures would then instinctively hunt or spread their webs where the prey abounded, and having eaten the soft parts, or sucked the vital juices, the wings and harder portions would be left lying about, so that when my resurrectionary trowel lifted the long-forgotten relics of the past, it also lifted the *disjecta membra* of the recent dead, and consigned them to one common inspection under my lens. This constant turning up of recent beetle or fly remains made the absence of ancient insects among the fossil dust more remarkable, and added another why and wherefore to the many that have been asked, Where have all the remains of Carboniferous insects gone that never one turns up amongst the remains of the creatures that preyed upon them? As in the hyenas' dens of the interglacial caves the gnawed bones of their victims are found, so here we ought to find the wing-cases or wing-membranes of the creatures that the scorpions and eurypterids stung and sucked to death. The beetle cases are surely as indestructible as the skin of scorpions, and should have remained as undecayed and have been as readily found and recognized.

The underclay of the small coal in Kingscavel quarry yielded many spores and some bits of scorpion skin, but the coal itself was pure bitumen or mineral carbon, and contained nothing organic. Everything having life in it had gone to pot literally, and had been melted into bitumen, that old world churchyard adipocere, blacker than pitch, and quite as oblivious of what it once had been. The spores were different from those in the fakes, and sparser, being only those that had been buried where they lived and died; whereas those in the fakes had been gathered from a large area by streams or winds, and huddled into a common tomb.

The next quarry to which I shall refer as a notable instance of how interest in it was revived, nay, I may say, created, by black fakes and what was found in them, is South Coltpark quarry, Bishopbriggs. My recent acquaintance with it arose from a paper by Dr. Young and Mr. John Young, read before this Society (see *Transactions*, vol. ii., p. 283), in which it is stated that strata, composed of thin layers in which much vegetable matter was visible, occurred, and from this fact I thought there might be some good fakes in it. I found the quarry situated on the north side of Colston Road, between the highway from Glasgow to Bishopbriggs

and Fernbank House, and consisting of a large open square formed by heaps of rubble stone on the north and south, a high wall of solid sandstone on the east, and on the west by the old waste heaps of North Coltpark quarry, which were, however, divided from it by the North British Railway. The bottom of the quarry was covered by grass and a shallow pool of water lay under the east face. At first sight the chance of fossils of any kind even in black fakes seemed hopeless, as there were no bings of such as I had hoped there might be from the descriptions given by the authors of the paper already quoted. I saw only heaps of broken sandstone, quite amorphous, and sorely blackened with smoke dust. On the north side some bings of yellow weathered blocks proved that the cement-stone occurred in this quarry as in all the other quarries of Bishopbriggs, and looking across to the top of the thick sandstone, it was seen stretching all along the east face as a dark band some 12 or 14 inches in thickness. Wishing to have a closer look I crossed to the S.E. corner in order to climb up to it. In doing so I came to a wall of sandstone blocks built up against the rubble heaps to keep them from sliding down upon the men when at work. Looking at this wall I saw that many blocks of fakes had been built into it, and on examination found them to be black fakes so thoroughly weathered that large portions could be easily cut out with a trowel. Many had crumbled into dust, but others had only got the stoniness rotted out of them, and still adhered as bundles of laminæ, black and white alternately, in regular "Sunday-stone" fashion. These fakes were to the eye more grey than black from being highly charged with sulphur, which in weathering had turned into a grey dust which gave to even the blackest of the fakes so disreputable an appearance that at first I was rather doubtful of their good character. Having formerly got good things from sulphur-dusted material, I took two large bags of these fakes. These on being washed and examined turned out so good that I went three times afterwards for more, and brought away each time as much as I could carry, Atlas-like, on my back.

The yield in vegetable *debris* was chiefly in sacs which were innumerable, ranging from mere dots to some half an inch in length and about quarter an inch in breadth. Some were circular, others elliptical simple ovals, while a few were lanceolate. Most of them were quite free from carbonaceous matter, and translucent, letting the light shine through as if they were slightly tinted glass. Some

were very thin, mere films, while others were dense and dark-red, through which the light came darkly. These sacs are supposed by Mr. Kidston to be the bags which contained the microspores of lycopods such as *Lepidodendron*. The next most interesting vegetable remains were fragments of the epidermal tissue of plants, with dark and light stripes, or bars arranged lengthwise, and in the light spaces were rows of holes similar to those Mr. Kidston has stated to be the stomata or breathing pores of plants. There were also some very thin tissues, the true character of which could not be made out, but which were supposed to be skins of fruits like nuts, or *Cardiocarpi*. There were also, but only very few, bits of pinnæ of ferns completely mummified; carbonized wood was rare and only in crumbs.

Spores were not nearly so numerous in Coltpark as the sacs; still they were in considerable numbers. Some few were large with the surface sparsely pustulated; these were true *Triletes*; others covered with hairs and, having ears, were true *Lagenicula*. This was the most abundant form, and generally they were in good preservation. Mr. Kidston has made out four species of *Triletes* from South Coltpark—*Triletes* II., III., VI., IX.—and one species of *Lagenicula* and variety—*Lagenicula* I., and var. *major*. Descriptions and figures of these spores will be found in the paper "On Spores" (*Proc. Roy. Phys. Soc. Edin.*, vol. ix., p. 82).

The animal remains were superabundant and good, scorpion skin being in comparatively large pieces. Many of these were finely perforated with holes, or rather pores, some being scattered promiscuously, while others were in rows. Some had raised bosses which were darker than the main body of the skin; others had nicked or vandyked edges with raised margins probably the edges of carapaces or segments. Several ribbon-like bits which were evidently fragments of limbs were double with a thickened selvage. One of these had a single row of pores throughout the centre, length-ways, but none at the side, as in most others. Some fragments had wide holes like a piece of perforated zinc, the space occupied by the pores being equal to the solid interstices. Very few bits of eurypterid skin were found—just enough to say they occurred. Sometimes I thought I had got other animal remains, but I never could make certain of any, and had to let them pass with a point of interrogation attached in my memory.

I then tried to fix the place of the fakes in the section. It

was clear they could not have come from the position of those described by Dr. Young and Mr. Young, as they were said to lie below the sandstone wrought at South Coltpark, and therefore could not be touched in working it, and the 40 feet bed of sandstone exposed was solid throughout. They must be sought for above it, and on climbing to the top I found, beneath the cement-stone, a layer about a foot in thickness of black and white fakes, which, I thought, if weathered like those I got in the wall, would yield the same fossils. On taking a sample and proving it, I did not, however, get the same results or indeed anything tangible, as they broke into black and white grains. Still I think that the black fakes in the wall came from the same bed, but at parts where the vegetable and animal remains were less comminuted, and where they were laid down in more continuous layers, so that on weathering they came out whole as when deposited. The sand-stone here exposed is the same bed as that wrought in Crowhill, Huntershill, Kenmure, and North Coltpark, with the cement-stone lying on top of it in them all. As Crowhill and Huntershill quarries are on a higher level than South and North Coltpark, a fault is said by Dr. Young and Mr. Young to exist between them, and Mr. Hull has mapped it, but he seems not to have noticed the cement-stone in South Coltpark, as no blue line is laid down for it. I proved the existence of the cement-stone in South Coltpark by tapping it with my hammer in places there, while in North Coltpark it was in course of being lifted, and I walked over the top of it to examine the overlying shale. As the cement-stone of Bishopbriggs is without doubt the equivalent of Orchard Limestone, the fakes below it must be paralleled with the coal 18 inches in thickness below that limestone; and thus we have the same vegetable remains turned by dissimilar conditions into black fakes in the one case and into coal in the other, the presence of sand and mud or their absence making the difference between fakes and coal.

In the quarries hitherto cited the redemption has been due to black fakes occurring in thin layers of sandstone, but in some quarries the black fakes are intercalated in beds of blaes which, when thrown aside as waste, weather down to dust, and can be gathered and treated in the same way as limestone shale. The specimens of spores or animal skin got from blaes are generally in better condition than those from sandy fakes, as the sand grains or the mica flakes damage them by minute pitting through pressure.

Every bed or heap of blaes in any sandstone quarry ought therefore to be tested for spores. To show this by example, I may briefly quote two instances known to me. In Whinnyhall quarry, a mile N.E. of Burntisland, under about 40 feet of coarse, barren sandstone, occur 12 to 14 feet of layers of sandstone, each from 2 to 3 inches in thickness, and divided by partings of blaes from mere films to an inch or so in thickness. These which are shovelled aside weather readily, and have yielded many spores and pieces of scorpion skin in much better condition than those from the sandy fakes of Hailes or Kingscavel. In Gilmerton sandstone quarry there also occur two beds of blaes between the sandstone which have yielded great numbers of spores, sacs, and pieces of scorpion and eurypterid skin, in an equally good condition, and these have placed the sandstone of Gilmerton higher in my regard as a good hunting ground for fossils than the shale of the Gilmerton limestone is now or ever has been in my acquaintance with it.

The redemption of sandstone quarries has not come solely from black fakes, but also from the small coal seams sometimes exposed in them. One of these small coals occurring in Kingscavel quarry would, of itself, have been enough to have taken away the reproach of barrenness from it, if indeed the coal had not been quite outdone in that way by the fakes. Crowhill quarry, at the northern end of Huntershill, and a little N.E. of South Coltpark, has, in strata which lie above the cement-stone, two small coal seams which are separated from each other by 4 or 5 feet of shale or blaes. The lower of these coals is $2\frac{1}{2}$ inches, and the upper perhaps double that, in thickness. Under the lower seam are 2 inches of a hard earthy clay, so highly charged with sulphur that it is quite white, and full of small hairy spores of the kind styled by Mr. Kidston *Lagenicula* I. Under the upper coal seam there is also a layer of earthy clay in which the spores are more numerous and of a larger kind. It was rather difficult to cut out the lower clay, as I had to knock off the coal from above it with my hammer, and then cut it out in crumbs with my trowel. Further to the southward it was, however, much softer, and samples were got more freely.

Such are the facts which I think fully justify the title of this paper, and if any of my hearers agree with me that they in a geological sense redeem the quarries in which the fossils just described occur, I trust they will follow my example, and go and do likewise with the sandstone quarries throughout the district of

which this Society takes more special cognisance. And if such is done, I can safely promise that in the doing of it they will have much pleasure and a great reward. They will be led into places such as I have described Kingscavel to be, and will derive therefrom scenes and legends of the present and past life of the earth, which will make it seem dearer to heart and mind than ever before, and they will find objects which will stir the imagination into renewed vigour, and enable it to body forth and give a "local habitation and a name" to things hitherto undreamt-of in their philosophy. While handling the spores and sacs or other relics of this old-world vegetation, they will conjure up glimpses of quiet forests, of stately and ornate trees of *Sigillaria* or *Lepidodendra*, crowded with cones from which, as the winds ruffle the branches, the spores would scatter forth to replenish the earth with trees after their kind as long as Nature has need of them, and that with a profusion that makes sure that though "of fifty seeds she often brings but one to bear," care has been taken that the one shall always be forthcoming, and that the remainder shall not all go as "rubbish to the void," but be carefully gathered up into fakes or shales to furnish us with the pleasure and profit of studying such old-world remains, or into spore coal to supplement the sun when in these latter days by reason of old age he cannot give us the heat and light he formerly used to do!

Further, as the fragments of scorpion or eurypterid skin turn up to the bodily eye, among the crowd of mummified spores or sacs, the mind's eye will forthwith see scorpion-like creatures going about the roots of these same *Sigillariæ* or *Lepidodendra*, seeking and doubtless finding among the castaway spores and sacs, or beneath the dropt cones, or fallen fern fronds, other creeping creatures which they can catch, and sting, and devour, by the same means and with the same zest as their kindred do at the present time. Imagination fails us in that it cannot yet shadow forth the forms thus caught and forced into the service of a higher life than their own—those creatures, the true insects of the Carboniferous period in Scotland, of which at present we know nothing more than that they must have been—but their remains may yet be found if diligently sought for in the shales, or plant beds, where the fragments of the scorpions and eurypterids which preyed upon them so much abound.

No. XXXI.—Notice of the Late Professor de Koninck, *Honorary Member*. By James Thomson, F.G.S.

Laurent-Guillaume de Koninck, doctor in medicine, and Professor of the University of Liège, a most distinguished palæontologist, and an eminent chemist, was born at Louvain in Belgium, on 3rd May, 1809, and, entering the University of his native town, studied for the medical profession. On the completion of his curriculum, at an early age, he took the degree of doctor in medicine, with honours in other departments of scientific inquiry. In 1834 his eminence as a student attracted the attention of the Government, and, in order that he might travel and acquire a knowledge of chemistry in other countries, he was at its expense sent to travel. At Paris he then studied in the laboratories of Gay-Lussac and Thenard, at Berlin with Mitscherlich, and with Baron de Liebig at Giessen. In 1835 he was elected a fellow of the University of Ghent, and placed in charge of the course of industrial chemistry. His removal to Liège towards the end of the following year was at his own request, and there he taught organic chemistry. In December of the same year the Royal Academy of Sciences of Belgium elected him a corresponding member, his nomination as member dating from 1842. Though he worked assiduously, both as student and as teacher of chemistry, and made some important discoveries in that department of science, he found time in the intervals between his numerous duties to study the Carboniferous fauna of Belgium. He was a close observer, a careful collector, and a painstaking note-taker, the most minute differences in structural details being carefully examined and recorded.

With that eminently characteristic industry which distinguished him throughout his long and honourable career, he soon acquired sufficient data to warrant the issue of his first palæontological paper in 1837. Amongst his numerous contributions to science, both chemical and palæontological, his well-known "Descriptions des Animaux Fossiles qui se trouvent dans le Terrain Carbonifère de Belgique," in two volumes, with a supplement, which appeared between the years 1842 and 1851, is indispensable to the student of the fauna of the Carboniferous system.

His fame became more widely known, both as a chemist and as a palæontologist, inducing not only his own countrymen, but also those of other nations to confer upon him numerous honours. In 1846 he was elected Knight of the Legion of Honour, and in 1852 had the order of Leopold conferred upon him, also the order of the Red Eagle of Prussia. As a mark of their appreciation of his researches, the Kings of Prussia and Italy awarded him their great gold medals for his important scientific works, honours awarded only to the most distinguished scientific men. In 1853 he was awarded the Wollaston Fund to aid him in his important researches, and in the same year he was elected one of the Foreign Members of the Geological Society of London. Professor de Koninck was member, or corresponding member, of numerous learned societies; amongst others—the Academy of Medicine of Belgium; the Academy of Sciences of Turin and of Munich; the Geological Societies of London, Berlin, and Dublin; the Philomathic Society of Paris; the Imperial Society of Naturalists of Moscow; the Imperial Mineralogical Society of St. Petersburg; the Dutch Society of Sciences of Haarlem; the American Philosophical Society of Philadelphia, etc., etc. On several occasions he was selected by the Belgian Government to adjudicate on the merits of competitors for scientific honours, and in 1862 he was delegated to report on the chemical products exhibited at the International Exhibition of that year in London.

Professor de Koninck's first publication appeared in 1833, when he was comparatively a young man, and during the intervening period till 1887 he issued not less than from sixty to seventy separate memoirs, some of which were exhaustive and extensive in their character, and, bearing the imprint of originality and care, became indispensable adjuncts to the working palæontologist. But he did not live to finish his colossal work on the fauna of the Carboniferous Limestone of Belgium, which was intended to be a summary of all his investigations of the fauna of that system. He had completed the descriptions of the fishes, the cephalopoda, the gasteropoda, and the lamellibranchiata, forming volumes 2, 5, 6, 8, and 11. The volume containing descriptions of the brachiopoda was also nearly completed. In the last letter I had the honour of receiving from him shortly before his lamented death, he feelingly refers to his continued illness from brain fever, and his inability to continue his investigations; and he pathetically states that he had

only twenty-seven species of brachiopoda to describe, to complete his memoir of that group. Had he lived to finish this great work, it would have been (and is, so far as it goes) the most exhaustive palæontological treatise that has ever been issued. Even in its fragmentary state it places the author in the eminent position of ranking with his late, and often referred to, friends, Professor Louis Agassiz and Dr. Thomas Davidson, F.R.S.

The memoir by Professor de Koninck on the corals of the Carboniferous System, 1872, "Recherches sur les animaux fossiles du Terrain Carbonifère de la Belgique," is an important addition to the knowledge of that group of fossil remains, and bears the impress of careful work. His additions to our knowledge of the simpler groups, notably the genera *Amplexus* and *Zaphrentis*, are invaluable to the student of corals. Had he lived to overtake a general review of the corals he would have made some alterations, arising from a careful examination of sectioned forms which he made when visiting the writer in 1877. After examining the structural details of the genus *Amplexus*, and the nearly related *Caleophyllum* of Dana, and their merging into the genus *Campophyllum*, he was persuaded that the line of demarcation was extremely minute, and could only be determined by the thorough examination of sectioned specimens. This led to his types of fossil corals being sent to me for comparison and identification with our Scotch specimens. The result enabled us to identify a number of species, and, if he had lived, would have resulted in a more intimate relationship to revise and complete the classification of the group.

Our deceased honorary member was alike distinguished by his scholarly attainments, purity of motives, and transparency of character. Information received, even from the humblest source, was not only gratefully acknowledged, but found a place in his masterly works. In the long and pleasant correspondence with which I was honoured, there were frequent references to even the most trifling information received from his numerous correspondents. His intense desire to add something new had no influence in inducing him to withhold honourable mention of the discoverer, as is sometimes done. He, like his late friends, Louis Agassiz and Thomas Davidson and many such eminent scientific workers, had been often indebted to the provincial and practical field workers, and with all such men the recording of discoveries, no

matter by whom they are made, finds a prominent place in their published works. From the sagacity displayed in the definition and arrangement of genera and species in his great work already referred to, which appeared in 1842 and 1851, Professor de Koninck's reputation rapidly spread to such a degree that fossils were sent him for identification from all parts of the world, and his careful examination of the most minute details, and comparison with examples from other countries, enabled him to identify forms with a wonderful degree of certainty. Thus the fame of his careful work not only added to his own reputation, but also aided all palæontologists, wherever they might be located, to identify genera and species with great certainty. As in all human work, there will be doubtless modifications of and additions to his colossal labours, but arising principally from the imperfect geological record. New forms will be discovered, and new facts revealed, which will necessitate a re-arrangement of the greatest author's works. Yet what Professor de Koninck has left as his contribution to the cairn of intellectuality is, and will continue to be, regarded as a never-dying tribute to his world-wide fame. The Council of the Geological Society of London conferred upon him in 1875 the Wollaston medal, one of the highest honours in their power to bestow. In 1872 he was unanimously elected an honorary member of this Society, and ever evinced a great interest in its welfare.

I cannot conclude these few remarks in memoriam of Professor de Koninck in more appropriate language than by quoting the words of Professor Judd in his presidential address to the Geological Society in 1888:—"Deeply beloved by a large circle of pupils and friends, honoured by many marks of favour, not only from his own sovereign, but from those of other states, and acknowledged all the world over as the greatest authority in all questions pertaining to his own particular studies, our distinguished foreign member died on the 16th July, 1887."

No. XXXII.—Note on a Section of Boulder-clay, containing a Bed of Peat. By Robert Dunlop.

[Read 31st May, 1888.]

About two miles east of the town of Airdrie, at Burnhead quarry, there has lately been exposed a section of clay, apparently Boulder-clay. I do not positively assert that it is so until I have made further investigations, and, therefore, I only wish now to make a statement of actual facts which can speak for themselves. Indeed I would not have brought the subject before your notice at all at this time unless I had thought that during the summer months there would be a good opportunity for some of the members to examine the section for themselves, and perhaps decide the question, especially as every one knows that when a section such as this is fresh, it is much better seen than after weathering influences have had an effect on it. I may, however, add that several geologists of note who have visited the quarry have expressed their opinion that the section is true Boulder-clay.

This section of Boulder-clay, containing a bed of peat which was brought to light through a downthrow of the dolerite on the north side of the quarry, is about 12 feet thick, and the Boulder-clay appears to lie both above and below the peat, but as it dips to the north, the thickness cannot be at present ascertained. The peat is 17 inches thick in the section; when split up into layers, as it readily does, it is of a pale-brown colour, but turns of a darker shade when exposed for a few minutes to the light. Embedded in it are boulders of various sizes, consisting of sandstone, gneiss, etc., but these seem to be irregularly scattered through it, and do not form any defined layer. One which I now exhibit was found almost in the centre of the peat bed by Mr. Wm. Connochie, and it can at once be seen to be water-worn, with faint traces of ice-markings. The sandstone boulders, some of which are large, are almost all in a very soft condition, but if carefully handled they can be seen to bear traces of being water-worn.

Mr. James Bennie of the Geological Survey of Scotland, and a member of our Society, who took two large bags full of the peat to wash, says that its chief characteristic is the extraordinary

number of seeds of plants it contains in thousands upon thousands, but mostly belonging to very few species. The seeds of the common Mare's-tail, *Hippuris vulgaris*, are found in layers, also those of the Bogbean, *Menyanthes trifoliata*. There is a complete absence of the remains of trees generally common in our peat beds, except leaves, which after examination may probably turn out to be those of the Willow.

Some layers in the peat are made up almost entirely of Mosses, plant life of every other kind being seemingly absent, and in the lower layers remains of Beetles are very plentiful. In some parts of the section the peat is found to be greatly contorted, more especially in front of a large boulder which is seen partly embedded in it. The force which seems to have caused this contortion or crumpling appears to have been directed from the west, and therefore corresponds with the direction of the ice-markings on the top of the dolerite (*i.e.*, from west to east). It would appear that this peat was laid down in water, and a remarkable feature in it is the absence of sand. Chemical analysis, after the sample was air-dried, gives the following:—Volatile matter, including water, 70 per cent.; ash, 6 per cent., of a bright red colour, being almost a pure oxide of iron. The particles of iron have been so well absorbed by the plants that if carefully burned their structure can still be seen.

Above the peat, a bed 11 inches thick is almost entirely made up of sand, with partings of a fine clay through it. Above this is the upper portion of the Boulder-clay. It is 4 feet thick, and has all the appearance of the upper layers of the Boulder-clay about Airdrie. On washing about 14 lbs. of it, I got a residue of 10 per cent. which would not pass through a fine sieve of 200 holes to the inch. This consisted of small pieces of sandstone, ironstone, quartz, gneiss, and other rocks, mostly all water-worn, and the larger and harder ones showing ice-markings. Above this Boulder-clay there is a bed of 2 feet of peat, with trees standing up through it, and which would appear to correspond with the modern peats around Airdrie. Above the peat is at present 3 feet of alluvium, but I have some doubt as to whether it does not consist of soil which was taken from the top of the quarry in its earlier stages. The larger angular stones are at the bottom, and the finer material on the top. Another noticeable feature in this section is the occurrence, about 18 inches above the lower peat and in the Boulder-clay, of a

layer about 4 inches thick of small specks of amorphous Vivianite, some varying in size from $\frac{1}{8}$ of an inch to 1 inch. The chemical composition of this mineral is $3FeOP_2O_5 + Fe_2O_3P_2O_5 + 15$ aq. It is a phosphate of iron, and is frequently described under the name of Blue iron earth. Within the last few years it has been found in its crystalline form in the cavities of bones of various animals discovered in some of the Ayrshire crannogs. Its occurrence here seems to denote that animal remains have been at one time present, though whether they belonged to some of the larger mammalia there is, as yet, no possible means of discovering.

Note by the Rev. Canon Fowler, Lincoln, on the Insect remains obtained from washings of the Peat in Burnhead Quarry, Airdrie, by James Bennie, Geological Survey of Scotland.

The beetles observed belonged to two groups, the Carabidæ or predaceous ground beetles, and the Rhynchophora or weevils, and were restricted to two or three genera.

CARABIDÆ—

Pterostichus, near *strenuus*—head, thorax, and elytra of several species.

Anchomenus—an elytron apparently belonging to a member of the genus.

Besides the above, there was an elytron of a large species apparently belonging to the Carabidæ, probably one of the larger *Pterostichi*.

RHYNCHOPHORA—

Otiorhynchus maurus—head and thorax of several specimens, and one perfect elytron. This species as far as Britain is concerned is almost if not quite confined to Scotland.

There were also a few fragments of elytra of a bright violaceous metallic tint which I could not identify with any species known to me.

List by Clement Reid, F.G.S., Geological Survey of England, of Seeds from Peat-bed in Burnhead Quarry, Airdrie, from washings by James Bennie, Geological Survey of Scotland.

Ranunculus aquatilis, Linn.
Prunus padus, Linn.
Potentilla Comarum, Linn.
Hippuris vulgaris, Linn. (ripe and unripe, some bitten).*

* In the interglacial peats from the Edinburgh district I found many seeds, especially those of the Bogbean, which had been gnawed, by mice I believe.—J. Bennie.

Apium nodiflorum, Reich.
Carduus, sp.
Menyanthes trifoliata, Linn.
Betula nana, Linn. (leaves only).
Empetrum nigrum, Linn. (berries and seeds).
Potamogeton, sp. (also embryos).
Carex dioica, Linn.
,, *rostrata*, Stokes.
Isöetes lacustris, Linn.

No. XXXIII.—Ancient Coal Workings in the Ell Coal, Glenclelland, Wishaw. By John R. S. Hunter, D.Sc., LL.D., F.R.Ph.S.E., *Honorary Member.*

[Read 14th April, 1887.]

[Abstract.]

After showing how the first use of coal amongst our prehistoric ancestors may have been brought about, the author touched upon its occurrence in a calcined form in the old crannogs and other early habitations, proceeding to describe as follows the discovery of unrecorded coal workings in the Wishaw district.

A curious discovery of old coal workings recently took place in Glenclelland Pit, Wishaw, where, when working the famous ell coal seam, the miners unexpectedly came into some old and disused workings. The method adopted for taking out the coal seemed to have been done in a remarkable fashion, but at the same time one of the safest which could have been chosen by an experienced manager of to-day. The entrance to these old drifts appears to have been on the banks of the beautiful Calder Water, on the Wishaw side, above Coltness Mill, although no outward evidence of any disturbance here exists, the sides of the glen being covered with large trees. To a probable point here for the opening to where the old workings were lately found would be at least 150 yards. The depth of the coal seam here would be about $5\frac{1}{2}$ feet, the roof coal being arched, and the width of the working places from 7 to 8 feet. The old miners had apparently a good idea of the quality of coal, as in these workings only the best seam was taken out. Wheelbarrows of some description were used to convey out the coal, as marks of wheel runs were visible. Prints of human feet were also observed on the soft clay or pave-

ment, the markings indicating that some soft material had been worn to protect the feet from sharp fragments. Apparently only the larger pieces of coal were taken, as small heaps of dross were to be seen on either side of the runs.

A curious wooden bowl or platter was found in the course of the exploration, but after being carried out to the carpenter's shop by the foreman for further examination, it crumbled into pieces. It was from 8 to 9 inches across, and about 3 inches in depth, and was thought to be made from the wood of the Whitethorn.

There are no existing records of any old coal workings in this neighbourhood, and, therefore, it is impossible to speak authoritatively as to their date, or as to the workers, but the fine workmanship displayed in the winning of the coal shows that they thoroughly understood the best and safest methods of working.

Dr. Hunter went on to state that from the form of the roof arch, and the excellence of the arrangements, he was inclined to believe that the workings in question had been made by the Romans or under their superintendence. Their military roads were still existent in the district, and as from the remains found in various places occupied by them it was evident they understood and applied the use of coal, it was no great stretch of imagination to suppose that they had mined on Calder Water.

No. XXXIV.—Glaciation and Raised Beaches in Jura and Islay. By James Anderson.

[Read 13th January, 1887.]

When passing down the Firth of Clyde a geologist never fails to admire the polished rock surfaces about Kirn. I had frequently wondered, however, why the rocks along its shores further south, as at Toward Point, Tighnabruaich, Ardlamont, and thereabouts, did not show the same freshness. Although when viewed from a short distance they everywhere exhibit undoubted ice-moulded outlines, they also show, when closely examined, very old and weathered surfaces. The same appearances are also presented on approaching the shores of Islay and Jura; where the numerous outlying small islets of trap rock show an excessively wave-worn, rutted condition. When they are seen from the deck of the

steamer this ancient appearance is strikingly remarkable, and at no point can any freshly glaciated rock-faces be seen.

When I first saw them I had a preconceived notion that these islands had been glaciated by ice moving down the Firth of Lorne, but a sail along their eastern shores dispels that idea. I expected to find a dressed outline when they were viewed from the north, and a rugged one when seen in the opposite direction, but the reality was that the former showed by far the rougher outline of the two. The shape and contour of the string of islands comprising Islay, Jura, Scarba, Luing and Seil, narrowing and shrinking in size till they vanish altogether, suggest the idea that the northernmost of them had sustained the heaviest assault of the marching ice, and had consequently suffered most, but the composition and structure of Jura altogether militates against such an idea. The whole western side of that island is composed of very friable quartzite sandstone, cropping out from the shore to the mountain-tops, and dipping inland at a very high angle. This sugar-like quartzite is so very loose in its composition as to be unfit for even the trifling buildings required in the island, and stone has to be imported for the purpose. On the eastern coast the island is guarded by immense buttresses of trap, till we get on to schists dipping into the sea, and extending from the Sound of Islay to Lowlandman's Bay. Between the schists, and the quartzites which form the main bulk of the island, a series of beds of a black mineral exactly like blind coal intervenes. It resists the hammer, and where it is built into dikes the action of the weather seems to have no apparent effect upon it. From beneath it rises the quartzite formation, of which the upper beds are very different from the lower. If these upper beds were denuded of all that now overlies them they would, I think, form one unbroken sheet of flinty glassy material, extending from the shore to the peaks of the Paps of Jura, which, but for them, never would have existed.

Such being the formation of the island, it seems to follow that a glacier travelling from the north down the Sound would attack the strata "end on," as we might say, though at some points, no doubt, projecting trap-covered headlands would have deflected the ice-flow into the heart of the island. It is difficult to conceive how moving ice, working directly into the seams and weakest sections of such strata as still remain, could have spared any of them at all. In fact, the great body of sugary quartzite could

hardly have remained unless it had been directly protected from the action of such a destructive agent as moving ice. The contour of the island and the surfaces of the harder rocks show sufficient proofs that they have been moulded by a great body of ice moving from the mainland towards the ocean, but all indications I could observe pointed to a movement from east to west, directly from Cantyre across the Sound of Jura. Such a stream would first encounter the great walls of trap which we see rising on the shore of Jura and in the small isles. It would then pass over the schists and the hard indestructible, flinty quartzites. I rather think there would not be much movement in the lower portions of a sheet of ice that would fill all these immense depressions, and at the same time cover the mountains of the mainland. But move it did, and its action is well seen at an elevation of about 1200 feet, on the neck or shoulder between Ben Glass and Ben-a-Chalois, which forms the watershed at the head of Asdale Water. The rocks here are the flinty quartzites, which continue upwards on each side to form the peaks named, but are here broken down. On crossing the watershed into Glen Asdale the level drops instantly about 400 feet, leaving a deep trench which shows where the ice had ploughed into the softer rocks beneath, and formed a corrie about one mile long, which extends from the watershed to Loch Asdale. There is hardly any fall, the little stream which gathers in it being mostly a series of half-stagnant pools. I think there cannot be any doubt that this curious depression has been formed in the way I have indicated, a trap dike which passes through it, and is planed down to the level of the soft sandstone surrounding it, being only noticeable by its green surface, and by its forming a waterfall where it crosses the stream. But this glen contains a curious enigma. A bank of loose incoherent rubbish—earth and angular stones of local origin—occupies its centre from end to end. This bank is about 50 feet high and 200 to 250 feet broad at its base. It is obvious such material could not have been left by a glacier of just sufficient power to come over the watershed from the east, but it seems rather to have been the work of a much more recent ice period, when the frozen snows from the surrounding hills were sufficient to scrape down the loose material from both shores and deposit it in the centre, but were lacking the power to clear it away.

The mountain range which culminates in the Paps of Jura seems

to have been of sufficient elevation to produce a local glacier, but the form of the mountains has carried it off mostly towards the north and west. On the north side of the range an enclosed valley lying in the centre of the island between Cnoc an Ime and Cnoc Mor nan Cnoc, and about three miles in diameter, seems to have been filled with ice and to have overflowed chiefly over its western border into West Loch Tarbert, but it has also escaped eastward through a narrow streamless glen debouching at Gatehouse, where it has polished the back of a large body of trap till it looks like an upturned copper pan, and in striking contrast to the decayed, ancient, weathered, and wormeaten-like appearance presented by the ice-moulded rocks both north and south of it.

The bottom and sides of the central valley show intensely polished surfaces everywhere. The valley is enclosed on the west side by two or three bosses of rock, and over and between these the glaciation has been especially severe. Where it has plunged down into Loch Tarbert the ice has grooved channels like artificial docks and canals through the rock, and this is best shown opposite the northmost outlet. A little to the eastward of this I observed on a precipitous face two deeply cut recesses in the rock-face, evidently formed by considerable streams, where no streams could possibly run now. I think they may have been waterfalls on the course of streams which drained the northern side of the ice-field, outlets of the water which may have accumulated on that side. Returning again to the eastern side of the watershed we see that the ice flowing eastward from the main range has brushed down all weatherworn rubbish, and has imparted a fresh and smooth appearance as far as it has extended. The heaviest stream of ice on this side has followed the course of the Corran burn, and has brought down a large quantity of detritus which fills the lower course of the valley. The stream has cut deeply into this rubbish, and the banks show no appearances of stratification in its upper reaches, but from the road down towards the sea increasing evidence of dressing and levelling is thus shown, as if the sea had stood high enough to spread the debris out as it was laid down. This moraine matter is full of angular stones and covers a considerable extent of ground; and I think that the sea must have stood at the 40 feet level when this glacier ceased to carry down material. About a quarter of a mile south of Corran Bridge, and separated from the road by a small field, is a curious vestige of its work.

It is a section of a rubbish heap evidently occupying the southern limit of the moraine accumulated by the glacier in the valley, and lying close to the foot of the hill. It looks exactly as if a contractor had been removing a little mountain of rubbish and had failed to complete his contract when about four-fifths were done. The sea has apparently had time to level all before it retired, except this little corner, and yet the material is so loose and free that I cannot conceive why it has been left, unless it has been protected by an ice-foot or stranded field-ice. A similar accumulation of debris is found further south in the course of the Chapel burn, but of greater depth. Between these two points the hillside is pretty well brushed down, and little foreign material is found, showing that the ice from the Paps had been moving down along the whole hillside between these two points; but both north and south of these places old and worn boulders from the mainland are abundant, and while the material through which Corran burn and Chapel burn cut their way is loose and brownish in colour, the Kiels burn, a little to the south of Chapel burn, cuts through a light-coloured Till of a totally different character, being much firmer, and not unlike fire-clay in appearance, and full of travelled and worn boulders largely composed of granite, while very few belong to Jura. All the material to be seen in the course of the Chapel burn belongs to the native rocks, but the Till and the most of its contents seen on the lower course of the Kiels burn seem to me to have been carried across the sound of Jura from the mainland.

After seeing the fresh foot-prints of the local glacier in Jura the mind instantly reverts to what is seen in the Firth of Clyde, and it needs no further argument to prove that the latest glacier which formed in Loch Long and travelled down the firth had never reached Toward Point. If any guess could be ventured as to the relation in point of time between the two periods, based upon the relative freshness of the glaciation, I would say that the interval separating the dates of the latest local glacier and the older glacier must have been immeasurably greater than the period which divides the local glacier from our own time.

During my visit I gave particular attention to the Raised Beaches of these islands. Such occurrences are undoubted facts, but there were some points connected with them which I wished to investigate. While the lowest Raised Beach is so natural and so clearly marked that the sea might return to-day and re-occupy the

tract, it is very different with the higher or 40 feet beach, of which the existence cannot be doubted, for the rolled gravel is there as the sea left it, though the hollowed and cave-worn rocks are rarely to be met with. Raised Beaches can be traced all round the islands, but I have not seen them so well developed as round the head of Loch-in-dal in Islay. The road from Bridgend to Port Charlotte is formed along them for about two miles west of the former place, and both the 25 feet and the 40 feet beaches cover perhaps a square mile each. The gravel of the higher level is more rounded and of rather smaller size. The lower level is so free from sand or soil that the rounded pebbles are still uncovered by herbage. They are bounded on the western side by a cliff composed of loose earth and angular stones. At the base of this cliff, and between it and the outer and higher terrace, there is a broad trench 5 to 8 feet lower than the level of the old beach. Like the moraine heap at Corran this cliff, nearly perpendicular, about 100 feet high, and composed of material easily washed away, could hardly have remained as it is unless it had carried an ice-foot. The trench at its base may have been its seat. I followed the landward margin of these beaches for some distance and found them sharply defined by the rising ground. At no higher level than 40 feet could I find any rolled stones—all being angular. Although the limits of the 25 feet level are generally marked by sea-worn rocks, I have scarcely found an instance where the 40 feet level is so marked. In these Raised Beaches in Islay the configuration of the land all round would readily lend itself to the action of the sea, but at no point on the landward side does the 40 feet level show any margin of sea-worn rock. As in other places, it is here bounded by a depression, which leads me to think that our coast has been clad by a continuous ice-foot when the sea stood at the 40 feet level. I now think that the limits of the contemporaneous glacier on the mainland may be traced with some exactness. The rough weathered appearance of the schists about Tarbert and the lower parts of Loch Fyne lead to the supposition that the glacier in Loch Fyne had not passed Ardrishaig. The hillsides about Tighnabruaich do not look as if they had been recently polished, and the great Clyde glacier, which has left its foot-prints on the shores, especially about Kirn and Dunoon, may not have reached the Cumbraes or even Toward Point.

No. XXXV.—Polar Ice-caps and their Influence in changing Sea Levels. By Sir William Thomson, LL.D., F.R.S., etc., Professor of Natural Philosophy in the University of Glasgow.

[Read 16th February, 1888.]

The subject I have to speak about this evening is not exactly geological. I may say that the immediate proposal to lecture on such a subject is to be found in an extract which I shall read to you from Dr. Croll's book on *Climate and Time*. In chaps. xxiii., xxiv., of this volume Mr. Croll deals with the physical causes of the submergence and emergence of land during the glacial epoch, and he has given some very curious, while at the same time mathematically correct, explanations of the effects due to a certain assumed displacement of ice from one hemisphere to the other. After loyally calling attention, in his opening words, to the fact of his having been anticipated by M. Adhémar, (in a work *Révolutions de la Mer*,) in the suggestion of heaped-up ice being a probable cause of the submergence and emergence of land, Mr. Croll proceeds to investigate in a very masterly manner the probable effect of an ice-cap of a given description. In this connection Mr. Croll refers to an article on the subject published by him in the *Reader* for January 13, 1866, and the extract which I will now read to you from this volume, *Climate and Time* (pp. 372-374), consists of a note written by myself, at Mr. Croll's request, in regard to the objection brought forward in that article :—

"Mr. Croll's estimate of the influence of a cap of ice on the sea level is very remarkable in its relation to Laplace's celebrated analysis, as being founded on that law of thickness which leads to expressions involving only the first term of the series of 'Laplace's functions,' or 'spherical harmonics.' The equation of the level surface, as altered by any given transference of solid matter, is expressed by equating the altered potential function to a constant. This function, when expanded in the series of spherical harmonics, has for its first term the potential due to the whole mass supposed collected at its altered centre of gravity. Hence a spherical surface round the altered centre of gravity is the *first* approximation in

Laplace's method of solution for the altered level surface. Mr. Croll has with admirable tact chosen, of all the arbitrary suppositions that may be made foundations for rough estimates of the change of sea level due to variations in the polar ice-caps, *the* one which reduces to zero all terms after the first in the harmonic series, and renders that first approximation (which expresses the *essence* of the result) undisturbed by terms irrelevant to the great physical question.

"Mr. Croll, in the preceding paper, has alluded with remarkable clearness to the effect of the change in the distribution of the water in increasing, by its own attraction, the deviation of the level surface above that which is due to the *given* change in the distribution of solid matter. The remark he makes, that it is round the centre of gravity of the altered solid and altered liquid that the altering liquid surface adjusts itself, expresses the essence of Laplace's celebrated demonstration of the stability of the ocean, and suggests the proper elementary solution of the problem to find the true alteration of sea level produced by a given alteration of the solid. As an assumption leading to a simple calculation, let us suppose the solid earth to rise out of the water in a vast number of small flat-topped islands, each bounded by a perpendicular cliff, and let the proportion of water area to the whole be equal in all quarters. Let all of these islands in one hemisphere be covered with ice, of thickness according to the law assumed by Mr. Croll—that is varying in simple proportion to the sine of the latitude. Let this ice be removed from the first hemisphere and similarly distributed over the islands of the second. By working out according to Mr. Croll's directions, it is easily found that the change of sea level which this will produce will consist in a sinking in the first hemisphere and rising in the second, through heights varying according to the same law (that is, simple proportionality to sines of latitudes), and amounting at each pole to

$$\frac{(1-\omega)it}{1-\omega w},$$

when t denotes the thickness of the ice-cap at the pole, i the ratio of the density of ice, and w that of sea-water to the earth's mean density; and ω the ratio of the area of ocean to the whole surface.

"Thus, for instance, if we suppose $\omega = \frac{2}{3}$, and t = 6,000 feet, and take $\frac{1}{6}$ and $\frac{1}{5\frac{1}{2}}$ as the densities of ice and water respectively, we find for the rise of sea level at one pole, and depression at the other,

$$\frac{\frac{1}{3} \times \frac{1}{6} \times 6000}{1 - \frac{2}{3} \times \frac{1}{5\frac{1}{2}}},$$

or approximately 380 feet.

"I shall now proceed to consider roughly what is the probable extent of submergence which, during the glacial epoch, may have resulted from the displacement of the earth's centre of gravity by means of the transference of the polar ice from one hemisphere to the other."

I wish you to notice particularly the last sentence of that note, for it is to that my attention has been called. I was quite unaware that by this statement I had placed myself under any obligation, but it so turns out. A friend suggests that the quotation marks as applied to that sentence, be here deleted, and the passage given as Mr. Croll's own. Mr. Croll may well have said the same, for after quoting my note he at once proceeds to carry out that intention. For myself I can only say that I have tried to fulfil my obligation, and I feel I can throw but little additional light on the subject. Nor do I need to do so, as it is quite unnecessary for me to carry out the intention, since Mr. Croll has done it with all the means that occurred to him as bearing on former estimates, in regard to this very important and difficult subject.

With regard to the effect on sea level Mr. Croll's principle, as set forth in pp. 368-369 of his book, is thoroughly correct, and shows the remarkable power he possessed of grasping the subject, and dealing with it by a simple geometric construction which led to the same result as Laplace's mathematical analysis. For the stability of the ocean it is necessary that the specific gravity of water be less than the specific gravity of the solid, and it is less as we know. The mean density of the earth is about $5\frac{1}{2}$—or more exactly 5·6—times the specific gravity of water. This statement favours Laplace's theory as to the requisite for stability, but it is curious that Laplace did not notice the simple view that if the solid part of the earth had a specific gravity less than that of water it would tend to float and leave the water on either side of

it. For example take a globe of liquid of any size (Fig. 1) and let us suppose a small spherical portion at A to become solid. The configuration of solid and liquid would remain stable provided the solidified portion remained of the same density as the liquid. If the solidified portion acquired a density greater or less than that of the liquid, the configuration as shown in the figure would become unstable, and the small sphere A would take the position A′ or A″, in either of which two cases the configuration would be again stable.

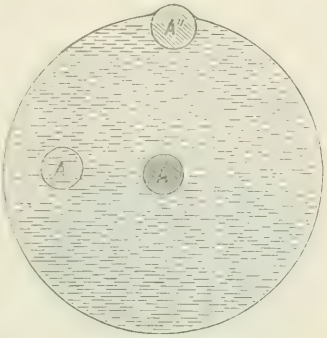


Fig. 1.

Look now at Fig. 2 and suppose the outer circle to represent the section of a globe 8,000 miles in diameter, and let the inner circle represent the section of an enclosed globe 2 miles less (7,998) in diameter. Suppose the outer envelope to be water, and the inner globe to be solid matter, of density equal to or greater than that of water, then the configuration of Fig. 2

Fig. 2.

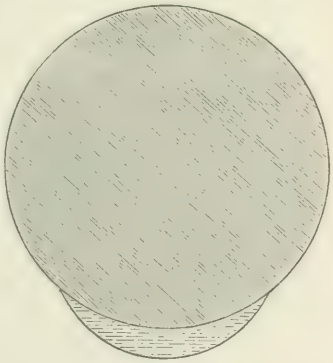


Fig. 3.

would evidently be stable. On the other hand if we suppose the inner globe to be solid but of density less than that of water, say equal to that of cork or wood, then the water would no longer form an envelope enclosing the solid, but would run together and the configuration of solid and liquid would be represented by a section such as Fig. 3.

Mr. Croll goes on to inquire what would be the probable effect, upon the level of the ocean, of changing the centre of gravity of the earth, if we suppose a quantity of ice (a polar ice-cap) to be transferred to one pole from the other. I shall just say one word as to the attraction of the polar ice-cap.

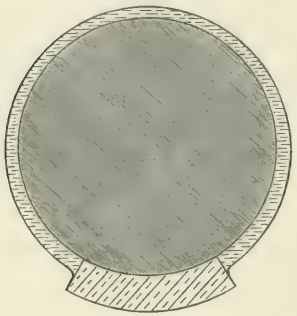


Fig. 4.

We have here (Fig. 4) a globe. Suppose that somehow or other a portion of ice was on the Antarctic continent, what would be the result? It would be that the polar ice-cap would attract the water, so that the water which was maintained at a certain height before that transference was made, would be drawn up to a higher level (as shown exaggerated by the outline in the Fig.) by the attraction of this mass of ice. The calculation for the result is merely a piece of mathematical book-keeping with which I need not trouble you.

There is just one other point which belongs to further explanation of Laplace's theory. That first theory of stability is really so clear that it is a wonder Laplace did not see it straightaway. But he was so intensely mathematical that he often did not see the simplicity of the results which he attained by complicated mathematical analysis. Suppose you shift a quantity of ice from one place to another on the globe; and suppose, instead of sea-water of its actual density, we had ideal water a twentieth part of the density of sea-water, then the attraction of this solid mass of ice upon the water would be calculated simply by the attraction of the ice upon the ideal water. The figure would be such that the surface of the ideal water would be everywhere perpendicular to the surface of the globe. But when we deal with real sea-water we have a piece of very delicate and nice mathematical book-keeping which reminds one of certain rules in Compound Interest. The ice attracts the fluid it displaces; but the fluid displaced itself attracts the remaining fluid and so contributes to the resultant attractive force. First calculate the amount of the attraction on the water due to the ice-cap alone; then calculate the increase of the attractive force due to the displaced water; then calculate this increase, to the second degree of approximation, and so on; and

thus you get at the result, just as in the very simple case put by Croll. Of course there have been different calculations. Mr. H. D. Heath and the Rev. O. Fisher made calculations which differed somewhat wildly from mine as well as from Croll's, but I believe them all to be consistent. My result, 380 feet, seemed to be immensely smaller than the others. In point of fact, Croll omitted to notice that mine referred to an ice-cap gathering on an ideal set of islands, and that I supposed the whole land to be distributed uniformly, and the ice to be placed upon the top of these islands. I took the actual proportion of the area of land to water, roughly estimated, as being one-third land and two-thirds water; that was in 1876. To bring my result into comparison with the others quoted, you must therefore treble it, because I took only one-third area as covered with ice. Three times 380 = 1140, which is my number on a certain supposition; while Heath's is 650 on a supposition not quite the same as mine. Pratt's estimate is still greater—something like 2,000 feet.

Now, if I could say anything to throw light upon the real question of extensions of ice in the southern or northern polar regions, and the effect of such extensions upon the sea level and upon the climate in past times, I should feel my attempt was certainly not insignificant. But I cannot even look upon such an attempt; I can merely point out certain fallacies and set certain limits to former suppositions. We cannot have an ice-cap on the Antarctic continent 12½ miles thick, as Mr. Croll has calculated. I think I can bring evidence against this. But Mr. Croll's argument does not at all stand upon that number; he is satisfied with a small fraction of it, 3,000 or 5,000, or 12,000 feet, instead of 65,000 feet. He is satisfied with an ice-cap of a comparatively moderate thickness as a sufficient cause for some most important fluctuations of sea level which geological history proves to have taken place. It seems to me that Croll is here meeting my case, and we may find the most probable explanation of some of our familiar changes of sea level—familiar even to people who are not geologists—in Croll's supposition of shiftings of ice either on the Antarctic or the Arctic hemisphere.

In the first place I shall ask you to imagine that the Antarctic continent for some unknown cause had at one time a distribution of ice over it thicker by 1,000 feet than at another time. To be more accurate I would say 1,200 so as to correspond with the area

equivalent to 1,000 feet of water. Mr. Murray has made a very careful estimate of the area of the Antarctic continent, which shows that the area is about one-fortieth of the area of the whole earth. Croll makes it more; but Mr. Murray has given us the more recent and more probable estimate. Now I shall merely ask you to think of a great ice-cap melted off the Antarctic continent, an ice-cap 1,200 feet thick equivalent to 1,000 feet depth of water. Imagine this mass of ice melting and flowing into the ocean; it would just raise the level of the ocean by one-fortieth of a thousand feet, a quarter of a hundred, or 25 feet. Our latest change of sea level here on the Firth of Clyde was only 10 feet. We do not know exactly the date, but it is quite certain that it was not within very many thousand years. The water-level in the Firth of Clyde was then 10 feet higher than it is now, and that change of level will, on the theory I have stated, involve the melting of only about 400 feet of ice from the southern continent, which could, of course, raise the water 10 feet all over the world. When the theory of gravitation is taken into account in the manner I have indicated, the water thus brought to one of the poles and converted into an ice-cap, or the water that flows away from the melting ice-cap leaving a deficiency of solid water, does by its own gravitation always exaggerate the effect. Before we go into any consideration whatever regarding the possibilities of thickness of Antarctic ice, I think we may say that if it is 500 or 600 or 2,000 feet thick at one time, it may be at another time more or less, and if so we should have corresponding changes of level all over the world. We have had such perfectly feasible cases put before us by Taylor, Heath, and others as to the thickness of ice at either Pole, and in respect to the level of the sea.

Before taking up the question of how thick the ice may be at either Pole, think a little of the shape of the earth and ocean around the North Pole. There is the North Pole (see Fig. 5, giving an outline chart). Here is Greenland and Iceland. You enter into the Arctic Ocean west of Iceland; then you come on to Spitzbergen, and further north to Nova Zembla, or again away to the east. This (the Arctic) ocean is merely a landlocked sea. The Behring Strait is only fifty miles wide and fifty fathoms deep, so that you may look upon the Arctic Ocean as practically stopped here. America is an island separated from the north-east of Asia by Behring Straits; and Europe, Asia, and Africa constitute

another island, though Africa may be considered a separate island because of the Suez Canal. The Arctic Ocean connects with the

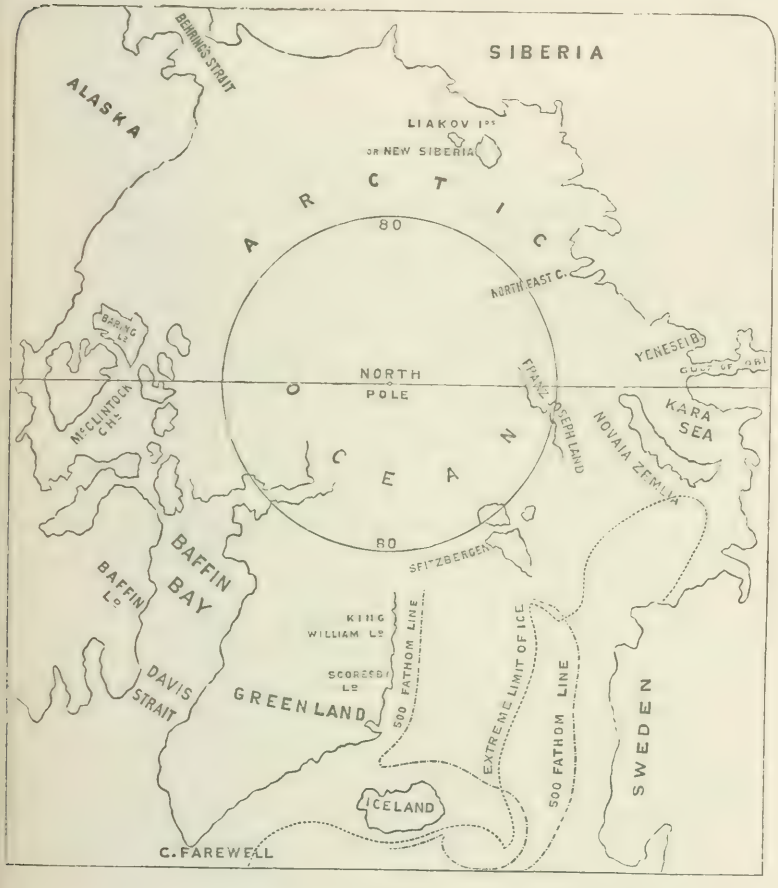


Fig. 5.

North Atlantic chiefly by the aperture between Norway and Greenland, with the large island of Iceland—one third of the way across from Greenland, and two thirds from Scotland. If a barrier were to be formed, as by raising slightly the bed of the ocean between the north of Scotland, Faroe Island, Iceland, and Greenland, the Arctic Ocean would become a lake. Such a barrier indeed already exists in a partial degree; we see from this chart that there is a zone of comparatively shallow water all the way

across from Norway to the Faroe Isles, Iceland and Greenland (see 500-fathom depth lines in Fig. 5). There is another opening by Smith Sound, and Captain Markham's expedition went up that narrow neck; but if it were closed the Arctic Ocean would practically become an inland lake.

Now what about the ice here? In the first place, so far as we know, the North Pole is under water. We know of no land north of Franz Josef Land. The farthest north that has yet been reached was by Captain Markham, who went 28 miles from the shore, and reached the latitude of 83° 20′ 26″ N. On boring the ice it was discovered to be only 64 inches thick, and they found water—76 fathoms—beneath. It was water 28 miles from the shore. They went over floating ice, and only succeeded in getting over something like 30 miles; for floating ice is exceedingly rough and hummocky in character, making the passage difficult for travellers. All we know then about the North Pole is that it is probably floating ice. There is also very strong, if not absolute, evidence to show that there is great freedom for currents to flow under the ice across the polar region. Here is a piece of wood (specimen exhibited) from the banks of a Siberian river carried down in a floe of ice. That ice floe with the wood was found in latitude 76° 30′ N., and longitude 40° W. The pine tree structure of the wood implies that it grew in a country far north. It came, as I said, embedded in an iceberg, and there is no possibility of that except by its being carried, by one of the great Siberian rivers which flow into the Arctic Ocean from the land of Siberia, across the North Pole into the latitude where it was found. There may be islands round the North Pole, but we know nothing of such. The Arctic Ocean, so far as known, has no very great island in the middle of it. This (second specimen shown) is a piece of another tree which was found fixed in an iceberg that floated across the North Pole, and there is the mud which was found on it. The wood is evidently a piece of a fir tree, with branches chiefly on the one side.

I want now to consider the physical properties of ice, so as to learn what limits, if any, these may give to a possible thickness of floating ice or of an ice-cap. Can ice stand in the form of any iceberg 1,500 feet thick? Comparatively speaking, icebergs have been said to stand at a height of 600 or 800 feet: at least that was the assumed measurement. The highest iceberg recorded is

700 feet, but there is a doubt whether it was even so high as that. What then would be the physical condition of a mass of ice at the North Pole? Think of the ice with snow falling on it at the rate of 3 feet annually. (I always reckon in feet of water, so that if I speak of 3 feet of snowfall, I mean sufficient to form 3 feet of water when melted).

In considering this question I must first call your attention to Forbes's celebrated theory of the viscosity of ice, and his viscous theory of glaciers. Forbes has demonstrated it by experiment; having studied the glaciers moving down the Swiss valleys and compared their motion with that of pitch. And now I am going to show you that motion in shoemaker's wax. Here is a piece (first model) you see what it has been doing since last Monday when it was placed a roughly rounded lump on the board: it is now flattened out like a pancake. Then here is another piece of shoemaker's wax that was placed, on the 2nd December, 1886, at the bottom of this jar with 10 bullets on the top and 14 corks placed below. If you look at the bottom of the jar you will see signs of bullets at the bottom, and you all see that the corks are making way through the wax and will be floating on the surface by and by. I may inspect the corks a little by carving into one of them. Probably in a fortnight that one will have taken advantage of this aperture I have just made. Thus, you see, in little more than a year the bullets have all disappeared beneath the wax, and the corks are coming to the surface.

But there is another experiment going on in this same jar. Three small cylinders of wood were each weighted by a piece of lead attached to one end, so that each mass—wood and lead—just floated on water. On the 4th February, 1887, these three cylinders were placed on the surface of the shoemaker's wax, one with the weighted end down, another with the weighted end up, and the third on its side; and there you see what has been going on during the year. The first cylinder has sunk steadily into the wax; the second has toppled over and is sinking to a vertical position with the weighted end down; the third has attained a vertical position and is nearly as deep in the wax as the first.

I would call your attention to another illustration of the viscosity of this seeming solid. There is a piece of shoemaker's wax which was levelled down with heat and then allowed to become cold. Two months ago, on the 16th December, 1887, we

placed *on* its surface the 16 pieces of wood—cylinders and cones—which you see are very slowly sinking into the wax. Here again I have pieces of wood shaped, and some of them with lead attached, exactly as are those on the wax. See the positions they take, and how quickly they do it, when I throw them on this fluid substance—water. Look at this cone in water. That cone (in wax), now so much inclined, was upright on 16th December, and I shall not say where it will be in the course of a short time. There is a long cylinder in water—you observe it falls down on its side. Then here is a shorter cylinder in water—it falls into an inclined position. Here again we have a very short cylinder which would be clearly unstable with its edge down. Then we have a cylinder with lead on it—it is stable. It is a counter-part of that which floats in water with the lead up, and would also float with the lead down, but it was placed in its present position. Now, there you have floating bodies which in a second of time, in water, do that which those similar bodies *floating* in wax are to be gradually doing in the course of the next few years. So that it is only a question of time between water and the shoemaker's wax.

Look at that globe of shoemaker's wax floating in water. Just watch it; if you could watch it for a long enough time you would see what would happen. But to economize your time look at this second one, which was placed in water last Tuesday exactly as you see the first—a globe. It is now like a pancake. It has flattened itself on the surface of the water to a round cake, of which the section is shown approximately by Fig. 6.* Our water

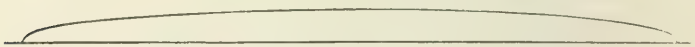


Fig. 6.

was slightly hot, as it would take two or three years to get as flat as that in cold water. We have hurried it up this evening by hotter water, but I am now going to leave it to itself.

Then here is a model—a wooden board having its edge shaped to represent the various forms of shore line, and covered with a layer of wax—illustrating the Arctic ice on the viscous theory. This was prepared last Monday, and has been somewhat hurried

* The curve is accurate for an *ice*-cap, and was drawn from the equation $y=b\left(1-\frac{x^2}{a^2}\right)^{\frac{1}{4}}$ with b (height) 2 inches, and a (diameter)=20 inches.

up by heat. You see the wax spreading itself on the plane, and tumbling over the edges. Here is another model, which was only started to-day, placed in water so that the board is just at the water level. You see we have the continental features complete with a long slope down to the sea on one side, a deep gorge, a precipice, and yet another slope down into the sea; and these variations of boundary are sufficient to show the various effects due to the shape of the land under a plastic body: everywhere ice flowing seawards breaking off when sea borne, and making ice-bergs.

That shoemaker's wax is a substance which we know and see to be plastic; here is a substance—ice—which we might not know to be plastic, but which Forbes proved to move as a plastic body in the Swiss glaciers. My brother's theory of the plasticity of ice, in virtue of melting by pressure and regelation, is admirably illustrated by an experiment of Mr. J. T. Bottomley. Here is a piece of clear ice having a piece of copper wire hung upon it, with a weight attached of 56 lbs. This wire will not go through the ice in less than an hour, but we see it already sinking into the ice—at the corners it is about half an inch in, and if we have time to look on it again we shall see the wire thoroughly embedded in the ice. This practically illustrates my brother's theory of the plasticity of ice—according to which one side of the wire presses into the ice, and in pressing cools it. The ice and the water coming together on the one side give rise to freezing on the other. But there is another and more complex case in which we have stress on the solid—a solid which if it melts will relieve itself from that stress. Such a solid relieves itself from stress by inter-molecular melting; and takes up the form free from stress by re-freezing.

In an investigation brought before the Royal Society of London last May by Dr. Main, it was stated that experiments made in the Engadine during February, 1887, with the temperature many degrees below freezing point, upon slabs of solid ice, showed that these yielded regularly as any other viscous body yields. Main's investigation gave perfectly definite results, though differing considerably with the temperature. Therefore, a bar of ice can be elongated. Take a bar of sealing wax; hang a weight to it, and it will yield. So a bar of cold ice several degrees below freezing point—in an atmosphere at least 8 or 10 degrees below freezing point—was found to elongate by one third per cent. per 24 hours; and the stress was 2 kilos. per square centimetre.

So also look at the shoemaker's wax filling this model, which illustrates the principal features in the path of say a Swiss glacier: not warm, but cold as it is here now, it will keep yielding constantly from year to year; working its way down this precipice, through this gorge, down this next precipice, out through this hole, and ultimately falling over the edges. Although it is brittle, it goes on day after day, month after month, yielding. I am not aware if my audience knows, what everybody knew many years ago, that a sealed letter left a long time seal down, flattens the seal with its own weight. We were always warned in those days not to seal letters for the tropics. Thus if you give it time enough, you will find the wax (alluding to the former model glacier) yielding, yielding, and yielding, according to the same laws, precisely as this mass of wax has yielded, aided by heat, in ten minutes—only with years instead of minutes. It would have taken months, I believe, instead of minutes, for an ordinary ball of shoemaker's wax to flatten in this way, if it had not been hurried by heat. We have made a calculation of this, but I will not go into the dynamics of the matter. There is, however, a distinct principle upon which you may calculate the equilibrium.

Turn again to this model showing the flattened ball: you may imagine this semi-fluid wax pulled in all round, held in as it might be by the sides of a containing box. Well it would then just take its level as water would. Now imagine the box placed in water and the sides taken away: the effect would be the same as if the wax were drawn out all round. There is no limit to the extent to which it would flatten itself, provided you did not keep adding material. But if you keep adding material, you arrive at a certain definite thickness. Suppose that to be a quantity of ice that covers a large area, and all of uniform thickness. How is this uniformity to be preserved? A great island covered with ice, 5 ft. thick and 10 miles across, with snow falling on it: at what rate must the snow fall upon it to keep its thickness uniform? Taking the calculation of viscosity of ice from Main's experiment, I find that ice 10 metres thick would require 33 centimetres per annum to fall upon it, to keep it of equal thickness. A metre is 39·37079 inches, or say 40 inches. The rate at which snow must fall upon ice 10 metres thick so as to keep its thickness uniform, would be 33 centimetres per annum. Double the thickness, or treble it, and you would require an increased snowfall to preserve it uniform—double

thickness requiring a quadruple fall, and so on. Thus if you assume a snowfall four times the amount stated, you would only get double thickness. So that if the thickness of the ice depended solely on its viscosity, you may say that, between reasonable limits as to amount of snowfall, the floating ice on the Arctic Sea could not be thicker than from 10 to 20 metres; that is to say, 10 to 20 yards = 30 to 60 feet. That is about the thickness that it can be, if there is nothing whatever carrying it away.

In the Arctic Ocean such an ice sheet might go on extending till it came to the shores, and then it would go on getting thicker and thicker, when it might make an Arctic ice-cap like the Antarctic ice-cap. But there is great difference of opinion in respect to the abstraction of ice. In the present condition of the Arctic Ocean there is an enormous abstraction of ice, with the Gulf Stream flowing in here (Fig. 5), and shooting away past Norway, and even carrying trees through the region of the North Pole. You may depend upon it that under the surface the ice is being simply washed away, and so kept down to 20, 30, or 60 inches in thickness. As I have said, Captain Markham's expedition found it only 64 inches thick within 399 miles of the North Pole, and we have no reason to believe that it is anything thicker, or very much thicker, at the very Pole. The free circulation through the Arctic basin is certainly what keeps down the thickness of the Arctic floating ice just now.

Suppose the circulation were stopped by a barrier running across from Norway by Iceland to Greenland, the result would be that the circulation of the water from the rest of the ocean into the Arctic Sea would be stopped and the ice would spread out. The whole ocean would be cooled down to freezing point, and then the ice would thicken, the average temperature being far below freezing point. The mean annual temperature within the Arctic circle is 10 degrees (Fahrenheit). Mr. Buchan has kindly prepared for me an estimate of the temperature, which I shall read.

"Mean annual temperature within Arctic circle, as a whole, is 10° F. Pole of cold appears to lie in about lat. 84° N., long. 150° W., around which an area of over 6,000 square miles has a temperature of −5° F. Two smaller centres of low temperature—one over Siberia about lat. 72° N., long. 123° E., and the other in North America, lat. 73° N., long. 105° W., over Melville Sound. Each of these centres has a temperature slightly below 0° F.

"In January the centre of the main low temperature area is in almost the same position as shown on the annual map. The lowest temperature shown is – 35° F., and this iso-thermal includes an area of nearly 2,000,000 square miles. The subsidiary centre over Melville Sound also shows a temperature of – 35° F., and is in the same position as on the annual map. That over Siberia is farther to south and east, being now over Werchojausk, lat. 67° N., long. 134° E., and is of great intensity, the mean January temperature of Werchojausk, taken over four years, being – 60° F.

"In July the lowest observed mean in the polar area is 35° F. No separate areas of low temperature appear, the coldest region to the north of Asia being in the Kara Sea, east of Nova Zembla. Low temperatures, 30° F. to 35° F., persist over Melville Sound, probably on account of the southerly direction of the ice-drift."

Under this condition it is perfectly clear that if the circulation of water from the rest of the ocean into the Arctic Sea were stopped, that sea would get filled up with solid ice, which would get thicker and thicker until we should have a prodigious ice-cap in the northern polar regions. We don't know if there was ever such a thing; but I hope geologists will find it out, and I see no reason why their ingenuity, and their skilful and laborious scrutiny of palæo-historic monuments, should not discover it.

Let us consider now for a little the state of matters at the South Pole. Just imagine this to be ice—this black line to represent the boundary of the ice. It has been intimated that at certain parts the Antarctic ice-cap terminates in precipices of 170 to 200 feet in height. Mr. Croll's calculation is invalid beyond a certain limit, because it has been made on the supposition that the slope is uniform from the shore line inwards. He estimates that at the South Pole the thickness of the ice-sheet would be 12 miles. I say the slope cannot be uniform, and the reasoning, dependent on the assumption of uniform slope, must be fallacious.

Let us look at the realities of this Antarctic Continent in the light of what we know regarding the viscosity of ice. Through the kindness of Mr. Murray of the *Challenger*, I am enabled to place before you this splendid map (from which an outline sketch is given in Fig. 7). You see here Victoria Land, explored by Sir James Ross. We have here high mountains running up to a height of 8,000 feet, and a volcano, Mount Erebus, 12,000

feet high—also discovered by Ross. There is an ice-barrier running 200 miles towards the west, which is everywhere about

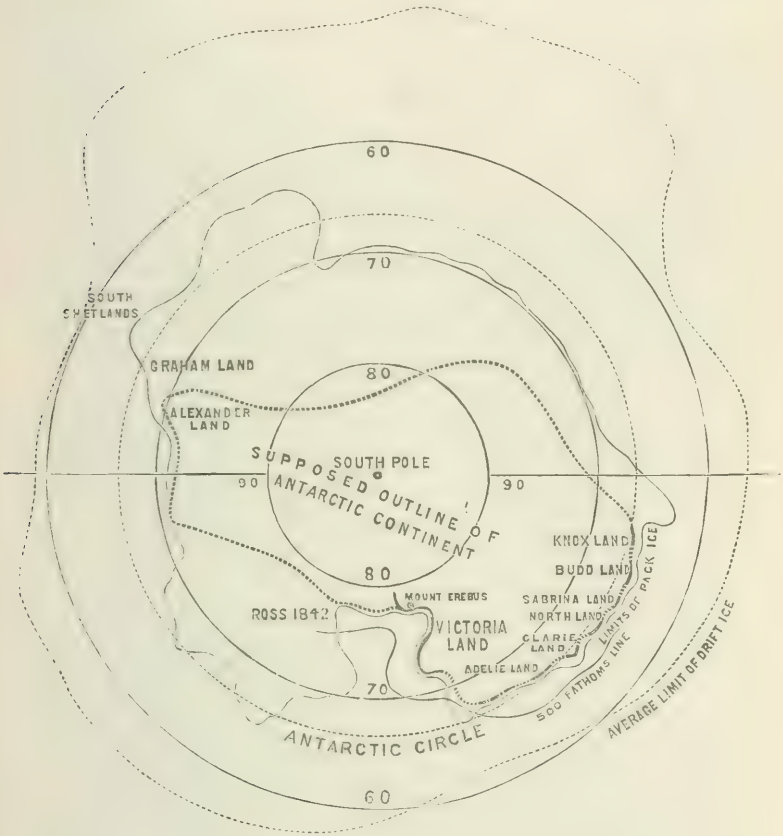


Fig. 7.

170 or 200 feet high above the sea. Here it is in our *model* Antarctic Continent already referred to. We break a piece off and thus we send an iceberg away. There is an ideal bay and gorge; a great high line, and ice slipping down into the water, and eventually breaking off, with ice below water nine times more than ice above it. It breaks away when it is ice borne and when it is water borne it will not break away. There [showing a sketch of an iceberg] is an ice precipice 170 feet above, and below 1,530 feet; and

here is the *Challenger* in a snow storm just after she has broken her jib-boom on the iceberg. The soundings taken here are described as giving 264 fathoms—just deep enough to float out one of these huge icebergs—at least they won't need to crawl along the bottom of the sea, if the neighbourhood of the shore there, is anything like the neighbourhood of the shore elsewhere. In some places you get a depth of 250 fathoms very close to the shore, but this sounding may be about 100 miles from the shore. In ordinary water the ice will float out; when it gets into water deep enough it will break off. Now let us take Mr. Murray's estimate of snowfall—75 centimetres per year (I am sorry I must give you results not always in metres or centimetres: easy things made difficult is the result of the English system of weights and measures)—which is worked out in an elaborate manner, founded upon the observations of expert German observers at South Shetland, just within the Antarctic circle. This would be something like 4 feet of snow and rainfall. I find, then, that with the viscosity taken from Main's observation, the thickness of the ice sheet at the South Pole would be 5,300 metres, that is about 18,000 feet. It is a very considerable thickness—about 3 miles—but only a quarter of Croll's estimate, which is much too high. The ice could not possibly stand at a height of 12 miles.

Questions as to the possible effect of this Antarctic ice sheet, or of changes in respect to its thickness, would be much too serious for me to enter upon just now. There are just two or three points I would like to consider. The amount of viscosity, and the probable slope of the Antarctic Continent, seemed to show that the ice cannot be very much thicker than 2,000 or 3,000 feet, and not nearly so much as 5,000 metres, as I have indicated—though I don't say that such is impossible at the South Pole, but only that it seems improbable. It is, however, quite possible that the absolutely different view taken by Mr. Croll may be true. It is also possible that the land may slope up to the South Pole, so that there may be no ice at all upon it. We really do want to know something about the South Pole. A memorial was, as you will remember, sent to Government asking them to assist in equipping an Antarctic expedition. The request has not been granted, but I think we may expect that Government will yet see their way to it. We are encouraged all the more, because we are assured it would be much easier to drive a hansom up the hill of the

South Pole than up the hill to our University. The hill of the South Pole is, in all probability, not more than a quarter of a degree, so that one could easily drive up it. Ross believed that if he could have found winter quarters there he could have walked over the Pole. If you once get ships up to the coast there (pointing to the chart) where Ross was, and get them comfortably frozen in, I don't see that there can be much difficulty in arriving at the South Pole.

Among the first questions to be ascertained is, Whether there is bare rock or ice at the Pole, and what may be the effect of underground heat there? It is quite possible that the solid rock may slope up to a mountain, and not be covered with snow at all. I think it is covered with snow; but there may also be bare crags, as in regions where snow cannot lie, and by boring into them something may be learned of the underground temperature. If we bore down a few thousand metres and find an increase of temperature at the rate of one degree centigrade per 27 metres, we may infer that it has been the same for many hundreds of years: if we find that the increase is smaller, we may be pretty sure that there has been a gain of ice; but if there is an increase of temperature of more than one degree we may infer an opposite state of things—that there has been melting, and that we are in a period subsequent to the melting. But take this case. Suppose the state of affairs to have been steady for about 5,000 or 10,000 years, or some little time like that, with an ice-cap 2,000 feet thick—and it is not at all improbable that that is the present condition—and suppose that under some of Croll's astronomical changes the sun became colder, and that snow began to fall twice as fast as now, and that it went on snowing for 2,000 years, the result would be that there would be a gain at the rate of, in round numbers, 2 feet per annum for 100 years—twice as fast as at present for 1,000 years. Set off against that the sloping down, and you get a very complicated problem. The terrestrial temperature would not follow it up. It would go for nothing. The thermal conductivity may be expressed thus:—How much heat would be conducted per annum through the 27 metres of rock? You can make a calculation, remembering that there are $31\frac{1}{2}$ million seconds in a year. The temperature increases by one degree centigrade per 2700 centimetres, and the thermal conductivity of average

rock (in centimetre-gramme-second units or "c.g.s.") is ·005. Thus we have the calculation :—

$$\frac{31\frac{1}{2} \times 10^6}{2700} \times \cdot 005.$$

The result is about 6 gramme centigrade units of heat per annum. Now it would take about 79 such units to melt a centimetre of ice per annum. So that is all underground heat would do ; in other words, it would go for nothing in respect to retarding the increase of the ice-cap. This shows that if we were to have this change of temperature and this double snowfall for several hundred years, there would be a very sensible addition to the quantity of ice, and a very sensible depression on the water elsewhere. But if the Antarctic ice-cap were to be greatly increased it would lower the water, diminish the circulation, and tend to cool the Arctic Ocean. Therefore, from this consideration alone, we should expect glaciation in the northern hemisphere simultaneously with an augmentation of the Antarctic ice-cap.

But by far the most potent influence for altering the climate in any part of the world is oceanic circulation. The sea is the great carrier of heavy goods. Our atmosphere of air, with its pressure of fifteen pounds per square inch, corresponds to 33 feet of sea. A column of sea-water 33 feet long (or 10 metres, or $5\frac{1}{2}$ fathoms) and square inch area, weighs 15 lbs. The atmosphere, mass for mass, is just equivalent to $5\frac{1}{2}$ fathoms of sea, but 33 feet depth is a mere fraction of our sea-water. And again, a quantity of water is of much greater capacity for heat than the same quantity of air, the thermal capacity of air being very much less than that of water. Briefly then we may say that in the transport of heat over the whole solid globe the air goes for nothing. The sea is the great carrier. The air, of course, has an enormous indirect effect in the shape of gales, moderate winds, or trade winds, and in moving the water It moves the surface of the water just as it moves the ships over the water. So that wind, indirectly, helps the sea as a heat carrier. The air, however, *distributes* the heat carried by the sea, and in this connection we may remember with the clergyman that there is no use praying for fine weather until we have a change of wind. The wind is the distributer, the sea is the carrier—the great carrier—in the transport of heat.

Additional Note to Mr. Bell's Papers.

[See Nos. XXI. and XXII., pp. 237-261.]

Instances of the longer axis of the boulders coinciding with the direction in which these rocky fragments have been transported are, as has been said, sufficiently numerous to be noted in the Reports as the general or normal position. But it is to be borne in mind that exceptions are also numerous, though these have not been so particularly recorded.

Recent observations during a brief visit to a number of the Swiss glaciers may for the present be summed up as follows:—

1. There is no absolute uniformity in the positions of the boulders carried down by these glaciers; nor, indeed, when the conditions are considered, should this be looked for.

2. On short glaciers, especially, and where the ice is much broken and crevassed, there is the greatest diversity of position.

3. But on the longer glaciers, and where the ice is for some distance comparatively smooth and unbroken, the prevailing—almost uniform—direction of the boulders is undoubtedly longitudinal, or parallel to the course of the glacier.

A large proportion of the stones in the lateral and terminal moraines—more than was apparent at first sight—have the same general direction. One might say this was chiefly the case as regards the larger boulders; but this impression might be due simply to these being the more conspicuous.

Further observation on these points is suggested as desirable.

Meantime we have little or no doubt, from what we have seen, that the tendency of boulders on all glaciers is to assume a longitudinal position, and that this is most observable, as might be expected, on the larger glaciers, where the obstructions are fewer in proportion to the mass, and produce the least disturbing effect.

D. B.

Oct., 1888.

*** Of the Boulders figured in Plate V. No. 1 is after a photograph for which we are indebted to Mr. Lumsden of Arden, No. 2 is from a sketch kindly taken by Mr. M'Oran Campbell.

PROCEEDINGS FOR SESSION 1886-87.

(29TH SESSION.)

SOCIETY'S ROOMS, 207 BATH STREET, 14TH OCTOBER, 1886.

Mr. JOHN YOUNG, F.G.S., *Vice-President*, in the Chair.

Mr. ROBERT DUNLOP exhibited specimens of *Aviculopecten papyraceus*, Goldfuss, *Orthoceratites*, sp., and other marine fossils, which he had lately discovered in the Upper Coal measures, at Calderbank, Airdrie, the horizon lying between the Kiltongue and Virtuewell Coals—a most interesting find—going to prove that certain thin layers in the Upper Coal series had been laid down under marine conditions. Remarks were made by the Chairman, who pointed out that similar thin marine bands had been recorded elsewhere from the Upper Coal measures of Lanarkshire, and from the Coalfields of Fife and of England, proving the presence of the sea over these areas during short intervals of time during the deposition of the strata of the Upper Coal measures. Mr. James Thomson, F.G.S., stated that in his belief there was no proof that these shells, though of marine origin, had been deposited in these beds under any conditions but fresh water ones.

The CHAIRMAN exhibited slabs of Carboniferous Limestone Shale, covered with markings of Dendritic "Wad" or Black Oxide of Manganese, from Nettlehirst Quarry, Barrmill, Ayrshire, and spoke of their occurrence and origin.

Mr. JAMES WHITE read a paper entitled "Notes from Glencoe," which was illustrated by a map of the district and a number of rock specimens. Some discussion on points raised in the paper ensued.

ANNUAL GENERAL BUSINESS MEETING, 11TH NOVEMBER, 1886.

Mr. WILLIAM JOLLY, F.G.S., *Vice-President*, in the Chair.

The HON. SECRETARY (Mr. Murdoch) read the Report of the Council for the past year, as follows :—

REPORT OF THE COUNCIL FOR 1885-86.

The Council of the Geological Society of Glasgow have once more pleasure in submitting to members their report upon the work of the past session, the 28th of the Society's existence.

MEMBERSHIP.—Your Council regret to say that the additions to the roll

did no more than balance the losses from death, and withdrawal (chiefly by members leaving the district), although last October a special circular asking each member to do his best to find at least one new member was circulated. It is evident that the total membership is by no means so large as the position and work of the Society warrant, and a special circular has again been sent out this year, in the hope that it will induce members to exert themselves to add new names to the roll. Life members are also wanted.

Finances.—From the report to be submitted this evening by your Hon. Treasurer, it will be seen that while the income of the Society has hitherto been sufficient to pay its way, and leave a surplus, there have been extra expenses during the year, and that an addition to the funds would be very welcome.

Meetings.—Nine ordinary meetings were held during the winter and spring months, and were attended by about the usual average of recent years —about 50—above a fourth of the membership.

By the kindness of Dr. Foster Heddle, of St. Andrews, two special meetings were held in the Large Hall of the Philosophical Society, in May, when he delivered a lecture on "Carbonic Acid in Nature, as evidencing design." Numerous illustrative chemical experiments were given, the required apparatus being furnished by the kind assistance of Dr. William Wallace, City Analyst, and Messrs. Baird and Tatlock, Chemical Dealers, Sauchiehall Street.

Papers.—Of the papers read at the meetings, several were of considerable importance and interest, while many specimens, usually accompanied by notes or remarks, were brought forward. Indeed, had time permitted, these remarks, and also some of the discussions upon papers read, might have profitably assumed larger proportions.

Of the papers may be named the following:—"Tarbert in Lochfyne," by Mr. James White; "Account of the Joint Excursion of the Edinburgh and Glasgow Geological Societies to Ben Nevis and the Parallel Roads of Glenroy, in July, 1885," by Mr. William Jolly, F.G.S., *V.P.*; "The Life and Palæontological Work of the late Dr. Thomas Davidson, F.R.S., of Brighton," by Mr. John Young, F.G.S., *V.P.*; "On Crystallization and Liquefaction, as influenced by Stresses in the Crystals, with special reference to Metamorphic Changes in Rocks, and Plasticity of Ice," by Prof. James Thomson, LL.D., F.R.S.E., etc., University of Glasgow; "Notes on the Carboniferous Brachiopoda of Scotland," with a revised list of the genera and species, by Mr. John Young, F.G.S., *V.P.*; "The Detached Areas of Carboniferous Deposits in Scotland," by Mr. Dugald Bell; "On the Succession of Rocks in the N.W. Highlands,—the problem, its history and present state," by Mr. William Jolly, F.G.S., *V.P.*; and "The Geology of Annandale," by Dr. J R. S. Hunter, F.R.Ph.S.E., *Hon. Member*.

The Excursions of the Spring and Summer were generally very success fully carried out, and were well attended on the whole. The list is as follows:—

Cathkin, 17th April, 1887, conducted by Mr. Walter Burns.
Paisley and Gleniffer, 1st May, conducted by Mr. M. Blair.

Gourock, 15th May, conducted by Mr. William Armour.
Barrmill and Kilwinning, 27th May, conducted by Mr. John Smith.
Torbanehill and Bathgate, 12th June, conducted by Mr. R. R. Horne.
Bowling and Auchentorlie Glen, 26th June, conducted by Mr. John Young, F.G.S., *V.P.*

At Cathkin, the volcanic tuffs of which Mr. Young had not long before told us in his paper on their occurrence in this horizon, were more particularly examined, and the pleasant afternoon was wound up by a visit to the hospitable residence of Mr. James Tullis, at Burnside.

At Gleniffer, several good photographs of the party, having the Carboniferous Limestone cliffs as a background, were taken by an amateur, with fine effect.

At Gourock, the works for the new Caledonian Railway from Greenock were inspected and thoroughly examined, through the kindness of Provost Kennedy, of Partick, the contractor.

From Barrmill, the members proceeded to Kilwinning, through the Lower Limestone strata, exposed in the cuttings for the new Lanarkshire and Ayrshire Railway.

At Torbanehill, the pits, where the last remaining portions of the famous mineral are now being worked, were visited jointly with the members of the Edinburgh Geological Society, the party afterwards dining together in the Royal Hotel, Bathgate, on the invitation of Mr. R. R. Horne, lessee of the workings.

On the last excursion—that to Bowling, etc.—Mr. Young conducted the party over ground classic to members of the Society, but not visited by them for many years previously.

As in 1885, an extended excursion, jointly with the members of the Edinburgh Geological Society, was planned for the last week of July, to visit Loch Maree and district, under the guidance of Mr. William Jolly, F.G.S. Many of the disputed points in the succession of the N.W. Highland rocks were visited and examined, and all those who had been fortunate enough to accompany the party, pronounced it to be a great success. It is to be hoped that these long excursions, so happily inaugurated by those which have already taken place, may be continued in future years.

The Library.—From the untiring work of the Hon. Librarian, Mr. James White, the Library has now assumed an aspect which it never before wore. A catalogue has been printed and circulated, and it is expected that members will now make an extended use of the stores of geological literature within their reach.

The Transactions.—Part I. of vol. VIII. is now all in type, and will, it is safe to say, be in the hands of members by next meeting. It contains most of the papers read during the last two sessions, and also a record of the Proceedings, so that for the first time for many years, the issue of the *Transactions* may be said to be up to date. The Council believe that this position, once attained, will not be allowed to be departed from, as early publication of papers in a Society such as ours is of primary importance.

Death and Withdrawal of Members.—At the first meeting of last

session, Mr. James Coutts read a notice of his lately deceased friend Mr. Andrew Patton, of East Kilbride, a corresponding member of the Society, and within a few short months Mr. Coutts himself has been summoned to join the great majority. A notice of Mr. Coutts, read by Mr. John Young, F.G.S., will be found in the new part [Part I., Vol. VIII., page 177] of the *Transactions*. A well known and long-continued member of the Society, Mr. John Dron, died during last summer. Owing to the fact that he had gone to reside permanently at Millport, Mr. David Robertson, F.L.S., F.G.S., resigned his membership, and the Council have therefore unanimously agreed to recommend that he should be elected an Honorary Associate.

J. B. MURDOCH, Hon. Secretary.

The HON. TREASURER (Mr. John Wight) read as follows:—

FINANCIAL REPORT FOR 1885-86.

Income is a little less than it was last year, being then £99 8s. 5d., and now £92 2s. 7d., or £7 5s. 10d. against the year 1885-86, arising from fewer new members being elected, and less arrears recovered. The members who paid subscriptions this year were 161, against 168 the year preceding. The difference is not very considerable, and experience has shown that the Society can count upon a membership of at least 150, without much fluctuation. The accounts are so plain that they require no particular explanation or remark. The ordinary expenditure has cost about two-thirds of the subscription revenue, leaving at least £25 a year from subscriptions and £10 or £12 from other sources to be applied to expense of printing *Transactions*. The Treasurer has looked into the Accounts for the last fifteen years to find the cost of ordinary expenditure during that period, and he has ascertained that it averages £50 13s. 11d., so that the observations just made seem to be sufficiently well supported. The property of the Society is stated this year at £465 4s. 9d., only £10 less than a year ago; but the collection of geological specimens, which has been valued for some years at £18, has now been entered at *nil*; so that the Society's stock has not diminished, but somewhat increased, during the past twelve months.

JOHN WIGHT, Hon. Treasurer.

The HON. LIBRARIAN (Mr. James White) then read as follows:—

REPORT ON THE LIBRARY FOR 1885-86.

In offering you my second Report as Librarian, I am pleased to be able to state that the confusion and disorder, which formed so marked a feature in the Library a year ago, have now passed away, and have given place to a more tidy state of things. Even the Augean stable down stairs has been cleaned up and presents a fairly neat and respectable appearance. This has not been accomplished without a good deal of labour and a good deal of money. I don't grudge the labour, and I hope no one grudges the money—so we shall be quits.

If the expenditure has been large, full value has been got for it. All arrears of bookbinding have been overtaken, and there is not a sheet in the premises up stairs or down which has not been examined and the utmost

made of it. Some publications are still incomplete, from the missing numbers being out of print, but otherwise every imperfect book has been completed and bound.

The bookcase down stairs has been altered to make it more commodious. We have secured from the Philosophical Society the use of one half of the commodious bookcase which stands at the end of the council room, and have altered it to suit our own purposes, so that we have now accommodation sufficient to permit of the extension of the Library, at its present rate of growth, for several years to come.

A new Catalogue has been printed and issued, and will, it is hoped, considerably assist members in the use of the books; and an interleaved copy, in which all new books are immediately entered, lies on the table.

Now that we are in a fair way of doing well, no such expenditure as has been incurred this year need again be necessary, provided that a sufficient sum of money is granted and spent annually in keeping things in order. Serial publications and Transactions of Societies must be bound and placed in the shelves as they are completed, or else "the last state" may become, if not "worse," as bad as "the first." New books must also be added to keep us abreast of the times.

For these purposes, as last year's expense has been so great, and as a considerable number of new books have lately been added, a grant of £5 for this year will probably suffice.

JAMES WHITE, Hon. Librarian.

The Reports were all unanimously approved of, and on the motion of Mr. David Forsyth, M.A., the Hon. Secretaries, Treasurer, and Librarian were awarded a hearty vote of thanks for the services they had rendered to the Society during the past year.

The following gentlemen were elected to fill the vacancies in the Council occurring at this date:—As Vice-President, Mr. Daniel M'Millan; as Members of Council, Messrs. John Young, F.G.S., Robert Dunlop, John Dougan, and John Howat.

Messrs. John Robertson and David Pearson were elected auditors for the ensuing year.

The following gentlemen were elected Ordinary Members of the Society:—Mr. John A. Burns, 42 Virginia Street, and Mr. Robert Guy, writer, The Wern, Pollokshaws.

Mr. WALTER BURNS exhibited, with remarks, specimens of a Fish Palate, and of *Lingula squamiformis*, from the Carboniferous shales of Burnibrae, Milton of Campsie, the horizon of strata there exposed being that of the Campsie and Hurlet series.

Mr. JOHN YOUNG, F.G.S., made some explanatory remarks upon the appearance and differences of Vein quartz and Quartzite, in regard to which there appeared to be, he said, no little confusion.

A number of Rock specimens were shown under the Society's and other microscopes kindly lent for the occasion by members. Mr. Joseph Sommerville took charge of the arrangements, and the many beautiful sections were much appreciated by the members present.

Society's Rooms, 207 Bath Street, 9th December, 1886.

Mr. D. C. Glen, F.G.S., *Vice-President*, in the Chair.

The following gentlemen were elected members of the Society :—

As Honorary Associate, Mr. David Robertson, F.L.S., F.G.S., Millport.

As Ordinary Members, Rev. Robert William Dobbie, 21 Hamilton Park Terrace, Hillhead; Mr. William Murray, Coalmaster, 148 Hill Street, Garnethill; Rev. W. W. Tulloch, Knowe Terrace, Pollokshields; and Mr. Andrew Wright, 3 Moray Place, Strathbungo.

Mr. William Jolly, F.G.S., exhibited a number of Bones of the Moa from New Zealand, and read a series of interesting notes upon the occurrence of the remains of this extinct bird. Mr. John Young, F.G.S., Mr. D. C. Glen, F.G.S., and Mr. Murdoch also spoke on the subject.

Mr. John Young, F.G.S., read a paper on "The Composition and Modes of Occurrence of Crystalline Quartz, Vein Quartz, and Quartzites" [see page 278], illustrating it with sectioned slides for the microscope. The discussion which followed was taken part in by Messrs. Jolly, F.G.S., Bell, Sommerville, and Glen, F.G.S.

Society's Rooms, 207 Bath Street, 13th January, 1887.

Mr. Daniel M'Millan, *Vice-President*, in the Chair.

Messrs. John Gardner, Quarrymaster, Ballachulish, and 21 Clyde Place; Andrew Brown, 21 Roselea Drive, Dennistoun; and John Main, F.G.S., Partick, were elected Ordinary Members of the Society.

Mr. Robert Craig, Langside, Beith, *Cor. Mem.*, read a paper on "The Horizons of the Mammoth Bed of Kilmaurs and Dreghorn, Ayrshire." [See page 213.]

Remarks on the subject were made by Messrs. John Young, F.G.S., James Steel, Adam Knox, Dugald Bell, and others.

Mr. James Anderson read a paper on "Glaciation and Raised Beaches in Islay and Jura." [See page 316.]

Some discussion followed, and was taken part in by Messrs. Dugald Bell, John Young, F.G.S., Sommerville, and other members.

Society's Rooms, 207 Bath Street, 10th February, 1887.

Mr. William Jolly, F.G.S., *Vice-President*, in the Chair.

Messrs. Thomas Richmond, L.R.C.P.E., Surgeon, 26 Burnbank Terrace, and William Sinclair, Grange, Bothwell, were elected Ordinary Members of the Society.

Mr. Robert Dunlop exhibited a specimen of *Glyptoscorpius* from the Upper Coal measures at Mount Vernon, Lanarkshire. Mr. John Young, F.G.S., noted some of its peculiarities, and said the specimen was in a

measure unique in character, from its great rarity and fine state of preservation.

Mr. Joseph Sommerville exhibited a series of Rock specimens from Canada, including examples of Laurentian Gneiss, Granite, Limestone, Apatite, Mica, Serpentine, Strontianite, etc.

Mr. James Steel, on behalf of Mr. Thomas Scott, *Corresponding Member*, read a paper entitled "Some Notes on the Geology of the District around Tarbert, Lochfyne." [See page 262.] The paper was illustrated by specimens of the rocks referred to. Mr. John Young, F.G.S., made some remarks on the subject.

Society's Rooms, 207 Bath Street, 10th March, 1887.

Mr. D. C. Glen, F.G.S., *Vice-President*, in the Chair.

Mr. John Fowler, 4 Kelvinbank Terrace, Gray Street, Sandyford, was elected a Life Member, and Mr. James E. Sommerville, B.D., Minister of the Gospel, 11 Southpark Terrace, Hillhead, was elected an Ordinary Member of the Society.

Mr. John Smith exhibited a number of Volcanic Bombs, which he had taken from a bed of ash, twenty feet thick, exposed on the banks of the Duisk Water, near Dalry, Ayrshire.

Mr. William Jolly, F.G.S., *V.P.*, read a paper on "The Geology of Loch Maree and Neighbourhood," with reference to the controversy on the Succession of the N.W. Highland Rocks, with an account of the Joint Excursion by the Members of the Edinburgh and Glasgow Geological Societies there in July, 1886." The paper was illustrated by a large series of maps, diagrams, and specimens of the typical rocks of the district. At its close remarks were made by Rev. W. W. Tulloch, Messrs. John Young, F.G.S., Dugald Bell, Murdoch, and others, several of whom had taken part in the excursion referred to.

Society's Rooms, 207 Bath Street, 14th April, 1887.

Mr. D. C. Glen, F.G.S., *Vice-President*, in the Chair.

Mr. John Young, F.G.S., and Mr. Robert Mason, F.L.S., exhibited mounted specimens of a small Stalked Crinoid, *Allegecrinus Austinii*, from the Lower Carboniferous Limestones of Howood, Renfrewshire, and Auchenskeoch, near Dalry, some remarks on the species and the localities where it was found being made by the former.

Mr. D. C. Glen, F.G.S., *V.P.*, exhibited a number of fine specimens of Trilobites from Silurian and Carboniferous strata.

Mr. J. B. Murdoch, *Hon. Sec.*, exhibited specimens of Sandstones and Sandy Shales from the cuttings of the new branch of the G. and S. W. Railway near Greenock, which showed induration from the action of pressure and heat, and subsequent decomposition, and upon which further remarks were made by several members.

Mr. G. G. Henderson read a paper entitled "Description of an uncommon dark brown Carbonaceous Sandstone" found in the neighbourhood of Tweed River Heads, Australia. [See page 276.]

In the absence of Dr. J. R. S. Hunter, *Hon. Member*, Mr. J. B. Murdoch, *Hon. Sec.*, read a paper entitled "Notes on Ancient Workings in the Ell Coal near Wishaw, Lanarkshire." [For an abstract see p. 315.] Some discussion ensued, and the members who spoke did not seem to think the author had proved his theory that the workings described were Roman. The great probability was that they were of a much more recent date.

Society's Rooms, 207 Bath Street, 12th May, 1887.

Mr. Daniel M'Millan, *Vice-President*, in the Chair.

Mr. John Boyd, one of H.M. Inspectors of Schools, 9 Princes Square, Regent's Park, was elected an Ordinary Member of the Society.

Mr. Dugald Bell read a paper "On the Glacial Phenomena of Scotland, with reference to the Reports of the Boulder Committee of the Royal Society of Edinburgh." [See page 237.]

An interesting discussion followed and was taken part in by Messrs. James Thomson, F.G.S., John Young, F.G.S., William Jolly, F.G.S., David Forsyth, M.A., and other members.

Society's Rooms, 207 Bath Street, 26th May, 1887.

Mr. William Jolly, F.G.S., *Vice-President*, in the Chair.

Mr. J. F. Bryden, 26 Shamrock Street, was elected an Ordinary Member of the Society.

Mr. Robert Dunlop exhibited a specimen of a large Scorpion-like Crustacean from the Lanarkshire Upper Coal measures. It seemed to be entirely new to science, and having been placed in the hands of Mr. B. M. Peach, Geological Survey of Scotland, it was hoped he would figure and describe it for the *Transactions* of the Society.

Dr. J. R. S. Hunter, F.R.Ph.S.E., *Hon. Member*, read a paper entitled "Volcanic Action and Earth Movements in the Upper Coal Measures of Lanarkshire." In this paper the author brought forward numerous examples of the great dislocations and faultings which had been from time to time observed in the rocks under notice, illustrating his observations and deductions by a large series of maps, sections, and specimens of local volcanic products.

Some discussion followed, and was taken part in by Mr. John Young, F.G.S., and several other members.

The Chairman then declared the 29th session of the Society to be closed, expressing a hope that the members would meet with renewed health and vigour to inaugurate another year of the Society's work in October next.

PROCEEDINGS FOR SESSION 1887-88.

(30th Session.)

Society's Rooms, 207 Bath Street, 13th October, 1887.

Mr. D. C. Glen, F.G.S., *Vice-President*, in the Chair.

The Chairman congratulated the members on the opening of the 30th session, and hoped that in the future, as in the past, the Society would do good geological work.

Mr. Robert Dunlop exhibited specimens of Crustacean remains from the Lanarkshire Upper Coal measures, including *Anthropalæmon Grosartii*, Salter, first discovered by, and named after, the late Dr. Grosart of Salsburg, parish of Shotts, long a corresponding member of the Society. The present specimens had been found in the shale overlying the ironstone, the stratum being apparently quite local, extending to at the most four miles, and at its broadest about four hundred yards. Remarks on the specimens were made by Mr. John Young, F.G.S., Mr. James Thomson, F.G.S., and others.

Mr. James White read a paper entitled "A Glimpse of Loch Maree, with Notes and Thoughts by the Way," and some discussion on various points raised in the paper followed.

Society's Rooms, 207 Bath Street.

Annual General Business Meeting, 10th November, 1887.

Mr. William Jolly, F.G.S., *Vice-President*, in the Chair.

The Hon. Secretary (Mr. Murdoch) read as follows :—

Report of the Council for Session 1886-87.

The Council have again the pleasure of submitting their Annual Report upon the business of the past session—the 29th in the Society's history—and they are happy to be able to say that the work has proceeded evenly and prosperously, but without anything of an eventful nature to chronicle.

The Membership has remained almost stationary, the number of names on the roll, though reduced on the one hand by the various causes which operate in this direction, having been strengthened by the addition of new

members. As the Council have frequently pointed out, the list might easily be enlarged, with considerable advantage to the Society and to all concerned. One Life Member was added to the roll during the year.

Of FINANCE it is more especially the province of your Hon. Treasurer to speak, and it will be found that he is able to report on the whole favourably of the situation in that respect.

The MEETINGS of the 29th session, nine in number, were taken part in by fully the regular average number of members, about forty, a fairly good attendance, considering the many counter attractions now open in Glasgow in the evenings.

The PAPERS and SPECIMENS submitted at the various meetings of the session were in many cases of high interest and importance. Amongst the former may be enumerated the following :—"Notes on Glencoe," by Mr. James White ; "Quartz as a Rock-forming Mineral," by Mr. John Young, F.G.S. [see page 288] ; "On the Post-pliocene Beds of the Irvine Valley, Kilmaurs, and Dreghorn districts," by Mr. Robert Craig, *Cor. Mem.* [see page 213] ; "Some Notes on the Geology of the district about Tarbert, Lochfyne," by Mr. Thomas Scott, *Cor. Mem.* [see page 262] ; "The Geology of Loch Maree and Neighbourhood, with respect to the controversy on the N.W. Highland Rocks, and an account of the Joint Excursion to the district by members of the Glasgow and Edinburgh Geological Societies in July 1886," by Mr. William Jolly, F.G.S., *V.P.* ; "Volcanic Action and Earth Movements in the Upper Coal Measures of Lanarkshire," by Dr. J. R. S. Hunter, *Hon. Mem.* ; "On the Glacial Phenomena of Scotland, with reference to the Reports of the Boulder Committee of the Royal Society of Edinburgh," by Mr. Dugald Bell [see page 237].

A number of these papers will be printed in the next part of the *Transactions*.

The EXCURSIONS during last season were well, and sometimes largely, attended, as they were arranged for localities easily accessible on Saturday afternoons. They were as follows :—

Giffnock and Orchard, Saturday, 16th April, conducted by Mr. James Anderson.

Barrhead and Arden, Saturday, 30th April, conducted by Mr. D. C. Glen, F.G.S.

Calderwood and Torrance, Saturday, 14th May, conducted by Mr. Dugald Bell.

Mugdock and Strathblane, Saturday, 28th May, conducted by Mr. John Young, F.G.S.

Inellan and Toward, Saturday, 11th June, conducted by Mr. William Jolly, F.G.S.

Kilbirnie and Beith, Saturday, 25th June, conducted by Mr. Robert Craig. (A joint excursion with the members of the Edinburgh Geological Society.)

An extra excursion was arranged for Balmaha, Lochlomond, on 2nd July, 1887, conducted by Mr. James Anderson, and was very successful.

No long excursion, like those taken in former years to Lochaber and to

Loch Maree, was arranged for this summer, but it may now be stated that an extended trip to the Oban district during 1888 has been planned, and will probably be carried out.

The Library has been in full working order during the year, and has been well made use of, a great improvement in this respect being noticeable. The binding of books in parts has been brought up to date, but though the outlay under this head has been beyond that of any former year, that is counterbalanced by the condition of the library. The Council hope that the books will be still more used than they have been.

Of the Transactions, no new part has appeared during the year, other expenditure having rendered it inadvisable to incur a new printing account. Arrangements are now being made to commence another part, which is expected to be in the hands of members at the close of the present, or the commencement of the following session.

Losses of Members.—During the year now closed, several well-known names have been removed from the roll by death. By far the most outstanding of these is that of Professor de Koninck of Liège, the celebrated palæontologist, elected an Honorary Member in 1872, when he visited Glasgow, and was entertained to dinner by a number of the members. Prof. de Koninck's reputation was worldwide, and the Council hope that a notice of his life and work will be contributed to the Society during the current session. [See page 308.]

J. B. Murdoch, Hon. Secretary.

The Hon. Treasurer (Mr. John Wight, C.A.) then read as follows :—

Financial Report for 1886-87.

Subscription income in 1886 was £80 10s. ; this year it is the same. In 1886 that sum included 11 new members and no arrears ; in 1887 it includes 13 new members and 3 arrears : consequently the revenue from membership has remained stationary. The members who have actually paid subscriptions are 158, against 161 reported last year—a small decrease. The Treasurer reported last year that for a long time the average cost of the ordinary expenditure had been about £50. It will be observed that it has not exceeded, during the past year, £41 14s. 7½d. The debts of the Society are under £10, not taking into account the expense that may have been incurred for *Transactions*, if any, about to be distributed at the present time. The income from Invested Funds has been a few shillings less than last year. It will be noticed from these remarks that the ordinary financial business of the Society has been carried on as usual on a fairly economical basis, and though £80 of the Society's investments have had to be called up, it was not to meet any ordinary outlay, but to help to liquidate the cost of the *Transactions* and of printing the Catalogue, which together totalled £105 1s. 3d., £6 17s. being still unpaid. The Catalogue cost £23 7s. 6d., and it may be well to avoid this expense for a good many years to come. In regard to the *Transactions*, the Treasurer reported before, and he repeats it now, that arrangements should be made that the expense of the current *Trans-*

actions and the ordinary expenditure should not, as a general rule, exceed the income of the Society for that year. The Accounts show that one Life Membership has been taken up.

JOHN WIGHT, Hon. Treasurer.

The election of office-bearers to fill the vacancies occurring in the Council at this time was then proceeded with, the following being the result :—

President, Sir William Thomson, LL.D., F.R.S., etc. ; Vice-President, Mr. Dugald Bell ; Members of Council, Messrs. D. C. Glen, F.G.S., Walter Burns, James Dairon, F.G.S., and James Thomson, F.G.S. ; Honorary Treasurer, Mr. John Wight, C.A. ; Honorary Librarian, Mr. James White ; Honorary Secretary, Mr. James Barclay Murdoch, F.R.Ph.S.E. ; Assistant Honorary Secretary, Mr. Gavin M. Pratt ; Auditors of Accounts, Mr. D. Pearson and Mr. Robert Gill.

Mr. William Dow, 165 Hospital Street, Glasgow, was elected an Ordinary Member of the Society.

Mr. JAMES S. M'LENNAN read a paper entitled "Notes on the Jordanhill Coalfield" [see page 271], and remarks on the subject were made by Sir James Bain, Mr. John Young, F.G.S., Mr. James Thomson, F.G.S., and other members.

Mr. D. C. GLEN, F.G.S., made some observations on the work of Section C. (Geology) of the British Association at the Manchester Meeting in September last, giving also a short account of some of the more interesting geological excursions then taken.

SOCIETY'S ROOMS, 207 BATH STREET, 8TH DECEMBER, 1887.

Mr. DANIEL M'MILLAN, *Vice-President*, in the Chair.

Mr. JAMES WHITE, Hon. Librarian, moved that £5 should be granted for the use of the Library, and this was unanimously agreed to.

The following gentlemen were elected members of the Society :—

As a Corresponding Member, Mr. Thomas Naismith, 6 Broompark Terrace, Dennistoun.

As Ordinary Members, Messrs. Alexander Bryson, 142 Trongate ; Andrew Meiklejohn, 52 Cromwell Street ; W. J. Millar, C.E., 261 West George Street ; James Miller, 1 Athole Terrace, Hillhead ; and Robert Mitchell, 24 Howard Street, Bridgeton.

Mr. JOHN YOUNG, F.G.S., read a paper entitled "Notes on the Carboniferous Genera of the Anatinidæ" [see page 291], which was accompanied by illustrative specimens.

Mr. DUGALD BELL, *V.P.*, read a paper entitled "Notes of the Society's Excursion to Calderwood Glen and Torrance Glen, East Kilbride, in May, 1887." After referring to the picturesque character of these glens, he described their more interesting geological features—the beds of sandstone, shale, coal, ironstone, and limestone exposed in them, and which were known as the Crossbasket ironstones and limestones—and by a sketch of

the district he indicated their position as members of the lower limestone series. He enumerated the principal localities for fossils, paying also a high tribute to the early labours of the Rev. David Ure in the locality, and to the more recent and long continued investigations of Mr. Andrew Patton of East Kilbride, a corresponding member, also to those of the late Mr. James Coutts, long a member of the Society.

Society's Rooms, 207 Bath Street, 12th January, 1888.

Mr. Dugald Bell, *Vice-President*, in the Chair.

Mr. D. C. Glen, F.G.S., exhibited a number of mineralogical specimens, including a fine crystal of Stibnite from Japan, Amazonstone from Peaks Pike, Colorado, and Wolfenite crystals from Arizona.

Mr. John Kirsop exhibited a specimen of Bituminous Coal, showing flattened spheroidal structure, also a specimen of Obsidian from New Zealand, and various specimens from Egypt, upon which some remarks were made.

Mr. Robert Dunlop exhibited a specimen of *Archithys sulcedens*, said by Dr. R. H. Traquair to be the only perfect specimen of this fish he had seen, it being usually represented only by its large laniary teeth.

Mr. Dugald Bell, *V.P.*, read a paper "On some Boulders near Arden, Lochlomond." [See page 254.]

Remarks on the subject were made by Messrs. James Anderson, Steel, John Young, F.G.S., William Jolly, F.G.S., and other members.

Society's Rooms, 207 Bath Street, 9th February, 1888.

Mr. Daniel M'Millan, *Vice-President*, in the Chair.

Ex-Provost Clark, Paisley, and Mr. Thomas Sinclair, 206 New Dalmarnock Road, were elected Ordinary Members of the Society.

Mr. D. C. Glen, F.G.S., exhibited a number of fine Mineralogical specimens, chiefly from North America, including varieties of quartz, rock-crystals, and cairngorms.

Mr. James Anderson read a series of notes on the Great Blue Lead and other "dead rivers" of California, with respect to their auriferous deposits, contributed by Mr. John S. Hitell and other American observers to the State Geological Survey. Mr. Anderson said he had brought forward these notes as bearing upon phenomena observed in our own country. Remarks were made by various members, Mr. William Jolly stating that the observations read afforded a beautiful corroboration of the phenomenon to be seen in the Scuir of Eig.

The adjourned discussion on Mr. D. Bell's paper "On some Boulders near Arden, Lochlomond," read at last meeting, followed, and was taken part in by Mr. William Jolly, F.G.S., Mr. John Young, F.G.S., and other members.

SPECIAL MEETING IN THE LARGE HALL, 207 BATH STREET.

LECTURE BY SIR WILLIAM THOMSON, F.R.S., President of the Society.

16TH FEBRUARY, 1888.

Mr. WILLIAM JOLLY, F.G.S., in the Chair,

Who was accompanied to the platform by Sir William Thomson and Dr. John Murray of the *Challenger*.

The CHAIRMAN, in introducing the lecturer to the meeting, referred to his past services to the Geological Society of Glasgow, and hoped that many years would elapse before he was compelled by nature to give up his scientific researches. His scientific insight easily reached the tidemark of high genius, and he had, like all true men of genius, an innate modesty and simplicity of nature which were equally beautiful and equally rare. In these respects they all felt that he followed his great master, Newton, with whose spirit he was so deeply imbued, and in the light of whose researches he had done so much admirable work.

[For the lecture see page 322.]

The Chairman then introduced Dr. John Murray of the *Challenger*, who, in proposing a vote of thanks to the lecturer, said the addresses which Sir William Thomson had delivered to this Society had been of enormous service to scientific men, and the one they had heard would have as great an influence as those of the past. The great difficulty on a subject like this had always been—what would happen from certain suppositions? Sir William had given them a great deal of information in this respect. He had supposed certain cases, and shown that others would follow. Proceeding to speak of barriers, Mr. Murray remarked that it might not be generally known there was a barrier which ran from the North of Scotland towards Norway and Greenland. He himself had taken the soundings, and found it was only 200 fathoms underneath the surface of the sea at the present time. It had been ascertained that it was covered with glaciated stones. It was, as it were, a great *terminal morraine*. Regarding the Antarctic continent, he said, from the information they possessed, and looking to the beautiful experiments placed before the meeting, there was no reason to suppose that there was a vast accumulation of ice on that Antarctic continent. Indeed, they were quite sure it was a very ordinary continent.

SOCIETY'S ROOMS, 207 BATH STREET, 8TH MARCH, 1888.

Mr. DUGALD BELL, *Vice-President*, in the Chair.

Mr. James D. Graham, Ayr Grammar School, Ayr, was elected an Ordinary Member of the Society.

Mr. JOHN YOUNG, F.G.S., exhibited under the Society's microscope a transparent section from the bed of Intrusive Dolerite found in connection

with the strata in which the fossil trees are imbedded at Victoria Park, Whiteinch. In one of the veins of the igneous rock recently exposed, and which passes through the roots of one of the trees, there are found the remains of a thin glassy surface on either face where cooling had taken place most rapidly. This glassy surface shows a spherulitic structure in which the spheres often have polygonal outlines through pressure contact while the rock was still fluid; and in these a fine radiated structure like that seen in some of the Arran Pitchstones has sometimes been developed, although the Whiteinch specimens only show the radiation in parts owing to the devitrification of the glassy structure which has afterwards taken place.

Mr. Young also exhibited a specimen of Gold-bearing Quartz from a lode in the Mawddach Valley, near Dolgelly, North Wales, which had been presented to the Hunterian Museum, in 1885, by Mr. George Lamb, Glasgow. In his remarks Mr. Young referred to the geological position of the auriferous lodes of North Wales and to the average amount of gold per ton of lode stuff which they are expected to yield, probably not more than one ounce per ton.

Mr. James Thomson, F.G.S., exhibited several specimens of Gold-bearing Rocks from North America, on which he made some remarks.

Mr. James Steel read a paper by Mr. Thomas Scott, *Corresponding Member*, entitled, "Notes on a Shell-bearing Clay at Roxburgh Street, Greenock." [See page 267.] Mr. Scott's paper was illustrated by a map of the locality.

Society's Rooms, 207 Bath Street, 12th April, 1888.

Mr. Daniel M'Millan, *Vice-President*, in the Chair.

Dr. John Murray, F.R.S., of the *Challenger*, was elected an Honorary Member, and Dr. James Smith, LL.D., St. Peter's Lodge, Uddingston, was elected an Ordinary Member of the Society.

Mr. John Young, F.G.S., and Mr. D. C. Glen, F.G.S., read a paper "On a section of Carboniferous Strata containing erect stems of Fossil Trees and beds of Intrusive Dolerite near Whiteinch." [See page 227.] After describing the beds with their fossil remains the authors spoke of the various considerations involved in their preservation, and concluded by expressing a strong hope that such an interesting epitome of geological history would be carefully protected for the benefit of students of geological phenomena and for the inhabitants generally.

The Hon. Secretary then read a paper contributed by Mr. Robert Kidston, F.R.S.E., F.G.S., "Note on the Nature of the Fossil Trees found at Whiteinch." [See page 235.]

An interesting discussion followed and was taken part in by Messrs. William Jolly, F.G.S., James Thomson, F.G.S., James Anderson, and other members, also by Bailie Storrie and several of the Commissioners of the Burghs of Partick and Whiteinch.

A Committee was appointed to meet with and assist the authorities of

the Victoria Park in the conservation of the Fossil Trees, consisting of Messrs. Glen, Young, Thomson, Jolly, Dairon, and the Hon. Secretary. It was agreed that 400 extra copies of Messrs. Young and Glen's paper should be thrown off for sale for the benefit of a fund for the purpose.

A number of photographic views and artists' sketches of the Fossil Trees were exhibited to the meeting.

Society's Rooms, 207 Bath Street, 10th May, 1888.

Mr. William Jolly, F.G.S., *Vice-President*, in the Chair.

Mr. Walter Dow, 2 May Terrace, Mount Florida, and Mr. J. M. Burnett, Duncairn Villa, Crosshill, were elected Ordinary Members of the Society.

Mr. John Young, F.G.S., said that since the date of last meeting several more stems of Fossil Trees, both upright and horizontal, had been laid bare at Victoria Park. As to statements which had been made in a Kilmarnock paper questioning the accuracy of his remarks last month on the spherulitic structure of the dolerite injected as thin veins through the Carboniferous strata at Whiteinch, he did not think it needful to take any formal notice of them as they were so utterly beside the mark.

Mr. Young then exhibited under the Society's microscope a section of the coarse crystalline Intrusive Dolerite from the same place, which plainly showed it to be composed of a basic felspar crowded with slender crystals of apatite. There were also numerous crystalline mixtures of magnetic iron, titaniferous iron, and sulphide of iron, along with augite and olivine, the latter of a pale green colour with a radiated fan-like structure due probably to some subsequent alteration in its crystals.

Dr. R. H. Traquair, F.R.S., keeper of the Natural History Department of the Science and Art Museum, Edinburgh, read a paper "On the Selachian genus of Fossil Fish, *Cladodus* of Agassiz," with a description of a remarkable specimen from East Kilbride, in the collection of Mr. James Neilson, and which he proposed to name after that gentleman, *Cladodus Neilsoni*. The paper was illustrated by a series of graphic drawings of structure, sketched by the author on the blackboard, and remarks were made by Mr. John Young, F.G.S., James Thomson, F.G.S., and James Neilson.

Mr. Walter Burns read a paper entitled, "Notes on the Heads of Ayr," which was illustrated by a map of the coast section and by a number of specimens of rocks and fossils of the district. [See page 287.]

Society's Rooms, 207 Bath Street, 31st May, 1888.

Mr. Dugald Bell, *Vice-President*, in the Chair.

The Very Reverend Canon M'Intosh, Airdrie, was elected an Ordinary Member of the Society.

Mr. Robert Dunlop read a paper entitled, "A Note on a Peat Bed in

Boulder-clay near Airdrie." [See page 312.] Remarks on the interesting nature of the occurrence were made by several members.

The Hon. Secretary, on behalf of Mr. James Bennie, Geological Survey of Scotland, read a paper on "The Redemption of Sandstone Quarries." [See page 298.] An interesting discussion followed, and was taken part in by Messrs. John Young, F.G.S., James Thomson, F.G.S., and other members.

The Chairman then declared the session closed and hoped that all present would be spared to meet next October, in good health, and with good accounts to give of their summer rambles.

Abstract of Treasurer's Accounts for the Year ending 30th September, 1886.

CASH ACCOUNT.

RECEIPTS.

Balance—Due by Treasurer at last Account,			£1 17 5
Annual Subscriptions—			
Subscriptions for current year, 150 at 10s.,	£75 0 0		
New Members, 11 at 10s.,	5 10 0		
		80 10 0	
Interest on Invested Funds,		9 14 5	
Publications Sold,		1 18 2	
Bank Account—Drawn,		40 0 0	
Balance due to Treasurer,		0 1 5	
		£134 1 5	

EXPENDITURE.

Transactions—			
Robert MacLehose, for Printing, etc.,			£73 7 0
Ordinary Expenditure—			
Rent, Insurance, and Attendance,	£12 11 6		
Collector's Commission,	3 14 0		
Stationery, Postages, and Petty Disbursements,	2 10 6		
Printing Cards, Circulars, Special Papers, and Receipt Book,	18 19 6		
Engraving,	0 18 1		
Disbursements by Secretaries,	6 3 4		
Disbursements by Librarian,	5 17 0		
Subscription to Palæontographical Society,	1 1 0		
Expenses at Professor Heddle's Lectures,	0 10 6		
		52 5 5	
Library—			
New Books,	£4 16 0		
Assistance in Compiling Catalogue,	3 3 0		
List of Foreign Books for Catalogue,	0 10 0		
		8 9 0	
		£134 1 5	

ABSTRACT OF TREASURER'S ACCOUNTS.—*Continued.*

STOCK ACCOUNT.

To Account for Binding,	£21	17	5	By Funds Invested—		
,, ,, New Books,	7	9	4	Loan to Corporation of Campbeltown,	£250	0 0
,, ,, Circulars, Cards, and Catalogue,	17	8	6	,, Books in Library,	160	0 0
	£46	15	3	,, *Transactions* in Stock,	60	0 0
,, Balance to Credit,	465	4	9	,, Furniture,	22	0 0
				,, Fossils (not valued),	0	0 0
				,, Microscope and Accessories,	20	0 0
	£512	0	0		£512	0 0

LIFE SUBSCRIPTION ACCOUNT.

1886—Sept. 30.—To Balance at Credit,	£120	15	0	1885—October 1.—By Balance,	£120	15 0

Abstract of Treasurer's Accounts for the Year ending 30th September, 1887.

CASH ACCOUNT.

RECEIPTS.

Annual Subscriptions—			
For current year, 145 at 10s.,	£72	10	0
New Members, 13 at 10s.,	6	10	0
Arrears for 1885-6, 3 at 10s.,	1	10	0
	£80	10	0
Life Subscription—Mr. John Fowler,	5	5	0
Interest on Invested Funds,	9	4	6
Repayment in Part of Loan of £250 by Corporation of Campbeltown,	80	0	0
Publications Sold,	2	5	7½
	£177	5	1½

EXPENDITURE.

Balance—Due to Treasurer at close of last Account,				£0	1	5
Transactions—						
Printing and Binding Part I., Vol. 8,	£68	18	9			
Engraving Plates,	4	18	0			
Printing Authors' Copies,	7	17	0			
				81	13	9
Catalogue—Paid to Account,				16	10	6
Ordinary Expenditure—						
Rent, Insurance, and Attendance,	£12	11	6			
Collector's Commission,	3	13	6			
Stationery, Postages, and Petty Disbursements,	0	19	3			
Printing Cards, Circulars, etc.,	11	8	0			
Disbursements by Secretaries,	4	16	6			
Disbursements by Librarian,	4	15	10½			
Subscription to Palæontographical Society,	1	1	0			
Fitting up Bookcases,	2	9	0			
				41	14	7½
Library—						
New Books,	£7	16	10			
Bookbinding,	25	8	0			
				33	4	10
Balance in Treasurer's hands,				4	0	0
				£177	5	1½

ABSTRACT OF TREASURER'S ACCOUNTS.—*Continued.*

STOCK ACCOUNT.

To Balance of Account for Catalogue,	£6	17	0	By Funds Invested—	
,, Do., for Cards,	1	8	0	Loan to Corporation of Campbeltown,	£170 0 0
,, Balance to Credit,	418	15	0	,, Books in Library,	160 0 0
				,, *Transactions* in Stock,	55 0 0
				,, Furniture,	22 0 0
				,, Fossils (not valued),	0 0 0
				,, Microscope,	20 0 0
	£427	0	0		£427 0 0

LIFE SUBSCRIPTION ACCOUNT.

1887—Sept. 30.—To Balance,	£126	0	0	1886—Oct. 1.—By Balance,	£120 15 0
				1887—Jan. 25.— ,, John Fowler,	5 5 0
	£126	0	0		£126 0 0

OFFICE-BEARERS FOR SESSION 1888-89.

President—Sir WILLIAM THOMSON, LL.D., F.R.S., &c.

Vice-Presidents.

For Three Years.	*For Two Years.*	*For One Year.*
Joseph Sommerville.	Dugald Bell.	Daniel M'Millan.

COUNCIL.

Wm. Armour, C.E.	D. C. Glen, F.G.S.	J. Young, F.G.S.
Wm. Jolly, F.G.S.	Walter Burns.	John Dougan.
Robt. I. Steele.	J. Dairon, F.G.S.	Robert Dunlop.
Jas. S. M'Lennan.	J. Thomson, F.G.S.	John Howat.

Hon. Treasurer—John Wight, C.A., 150 Hope Street.

Hon. Librarian—James White, 56 Rose Street, Garnethill.

Hon. Secretary and Editor of *Transactions*—James B. Murdoch, F.R.Ph.S.E., Capelrig, Mearns, Renfrewshire.

Assistant Hon. Secretary—Gavin M. Pratt, 104 West Graham Street.

Publishing Committee.

John Young.	William Jolly.	Gavin M. Pratt.
D. C. Glen.	Dugald Bell.	J. B. Murdoch, *Convener.*

Library and Museum Committee.

Wm. Armour.	D. M'Lennan.	R. I. Steele.
J. Sommerville.	John Howat.	Jas. White, *Convener.*

Finance Committee.

John Dougan.	R. I. Steele.
D. M'Millan.	John Wight, *Convener.*
Dugald Bell.	

Auditors.

Robert Gill. | David Pearson.

LIST OF MEMBERS at 1st December, 1888.

Honorary Members.

Year of Election.

1865. Geikie, Archibald, LL.D., F.R.S., F.G.S., Director-General of the Geological Survey of Great Britain and Ireland, Museum, Jermyn Street, London.

1867. Jones, T. Rupert, F.R.S., F.G.S., 10 Ulverdale Road, King's Road, Chelsea, London, S.W.

1867. Kirkby, James W., Ashgrove, Windygates, Leven, Fifeshire.

1867. Woodward, Henry, LL.D., F.G.S., British Museum, Natural History Department, South Kensington, London.

1867. M'Chesney, Joseph H., Professor of Geology, University of Chicago, U.S.

1871. Hull, Edward, F.G.S., &c., Director of the Geological Survey of Ireland, 14 Hume Street, Dublin.

1872. Thomson, Sir William, LL.D., F.R.S., Professor of Natural Philosophy, University of Glasgow, *President.*

Year of Election.

1872. Young, John, M.D., F.G.S., Professor of Natural History, University of Glasgow.
1879. Hunter, John R. S., LL.D., Daleville, Braidwood, Carluke. [1864]*
1883. Judd, J. W., F.R.S., F.G.S., Science Schools, South Kensington, London, S.W.
1883. Brown, Robert, M.D., F.G.S., &c., Ferslev, Rydal Road, Streatham, London, S.W.
1885. Heddle, M. F., M.D., F.R.S.E., late Professor of Chemistry and Mineralogy, St. Andrews.
1888. Murray, John, LL.D., F.R.S.E., of the "Challenger," Edinburgh.

Honorary Associates.

1867. Struthers, Thomas, Gourock. [1859]
1867. Croll, James, LL.D., Edinburgh.
1871. Crosskey, Rev. Henry W., LL.D., F.G.S., 17 Gough Road, Edgbaston, Birmingham. [1858]
1871. Horne, James, London. [1858]
1871. Farie, James, Canonbury, London. [1859]
1878. Lapworth, Charles, LL.D., F.G.S., Professor of Geology, Sir Josiah Mason College of Science, Birmingham.
1881. Wünsch, E. A., F.G.S., Carharrack, Scarrier, Cornwall. [1858]
1883. Traquair, R. H., M.D., F.R.S.E., F.G.S., Museum of Science and Art, Edinburgh.
1883. Geikie, James, LL.D., F.R.S.E., F.G.S., Professor of Geology and Mineralogy, University of Edinburgh. [1873]
1886. Robertson, David, F.L.S., F.G.S., Fern Bank, Millport. [1867]

Corresponding Members.

1859. Dougall, John, M.D., 115 Paisley Road, Glasgow.
1860. Sommerville, George, Thornliebank.
1862. Hunter, James, Ironmaster, Coltness.
1864. Grierson, T. B., M.D., Thornhill, Dumfriesshire.
1864. Mitchell, Rev. Hugh, LL.D., Craig, Montrose.
1865. Winchell, Alex., Professor of Geology, University of Michigan, U.S.
1866. Gloag, Rev. Dr. Paton J., Manse, Galashiels.
1866. Myers, Rev. Edward, F.G.S., 20 Summerhill Terrace, Birmingham.
1867. Craig, Robert, Langside, Beith.
1867. Gordon, Rev. Dr., Manse of Birnie, Elgin.
1867. Kerr, David, Wemyss Colliery, Fifeshire.
1871. Jack, R. L., F.G.S., Government Geologist, Townsville, Queensland.
1871. Jamieson, T. F., F.G.S., Ellon, Aberdeenshire.
1871. Kinahan, G. H., Geological Survey of Ireland, Dublin.
1871. Molyneux, William, F.G.S., Burton-on-Trent.
1871. Ward, John, F.G.S., 23 Stafford Street, Longtown, Staffordshire.
1878. Stewart, Rev. Alex., LL.D., F.S.A.Scot., Ballachulish Manse, Nether-Lochaber.

* The date *after* a name is that of election as an ordinary member.

Year of Election.

1883. Lindström, Professor G., State Museum, Stockholm, Sweden.
1883. Scott, Thomas, 14 Lorne Street, Leith Walk, Edinburgh. [1880]
1883. Smith, W. Anderson, Ledaig.
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James Barclay Murdoch, F.R.Ph.S.E.

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TRANSACTIONS

OF THE

GEOLOGICAL SOCIETY OF GLASGOW.

No. I.—On the Fructification and Internal Structure of Carboniferous Ferns in their Relation to those of Existing Genera, with Special Reference to British Palæozoic Species. With Four Plates [Nos. I. to IV.]

By Robert Kidston, F.R.S.E., F.G.S.

[Read 14th March, 1889.]

I have great pleasure in acceding to the request of your Secretary to bring this paper before the members of the Geological Society of Glasgow, especially as immediately surrounding this city are large coal-fields, rich in the remains of the extinct flora which is to engage our attention for a short time this evening.

This paper has been suggested to me from a question often asked by beginners in the study of Palæozoic Botany, "In what book can I find the descriptions of British species?" Unfortunately this question cannot be answered, as no complete work on the British palæozoic flora has yet been published, and what has been written on the subject is, with few exceptions, scattered through the *Transactions* of various Societies which are frequently inaccessible to students of fossil botany, except to those in some of our large centres of population. But let us suppose that the beginner has access to all papers hitherto published on British palæozoic botany, none the less will he soon meet with species which, if previously recorded from Britain, are certainly not described in any English work. One therefore must make their identifications in great part from the writings of foreign authors.

These volumes are expensive, and as very few of our libraries contain even some of the standard works on the subject, fossil botany in Scotland, and I might even say in Britain generally, has been but little studied. There are many intelligent collectors of fossil plants, but till there is a text-book on the subject in our own language, to the majority of them palæozoic botany must remain a closed but interesting chapter in one of the most inviting fields of natural history. It is therefore with the view of assisting our younger fossil plant collectors that the present paper has been prepared. It deals chiefly with those points of Carboniferous Fern Structure and Fructification which are sufficiently well known to enable a comparison to be made between past and recent genera, and this is done as briefly as possible. References to the original works are fully given, as half the battle is to know where to look for the description we wish, and the original works should in all cases be consulted.

As an appendix to this communication, I have given a list of the chief works and papers dealing with the fructification and structure of palæozoic ferns.

When studied with the object of discovering the affinities of extinct forms with those of existing genera, there is no more interesting branch of natural history than that of palæontology. It is true that the earlier workers in fossil remains did not always proceed on this line, and those possessed with the accumulated knowledge of generations are sometimes too ready to speak of the earlier workers in an uncharitable and often very unjust manner, forgetting that, of all branches of science, palæontology is that which depends more than almost any other on patient collecting and study. It is quite the exception to find a specimen showing the complete structure of the organism; its life-history and organisation have therefore to be made out, bit by bit, and pieced together from specimens often brought from the four quarters of the globe.

The original workers in palæontology, to whom all credit will be given by the true student, possibly did not appreciate the full importance of their investigations, nor with their limited knowledge of the subject could they see the important place it would occupy in the future.

The great discovery made by William Smith in the beginning of this century, that fossils, when treated with due caution, serve

as indices for the correlation of strata which may be widely separated in space, seems to have prevented the earlier geologists from seeing in the study of fossils the still more engrossing field of work in investigating and elucidating the relationships and affinities which exist between recent and extinct genera and species.

When it is remembered that each *formation* was at one time supposed to represent a *special creation*—and in the earlier days of geology this was the view almost universally held—it was probably thought that any close affinity between fossil and existing forms could not exist.

SECTION I.

FERN STRUCTURE OF EXISTING SPECIES.

Before attempting to understand fossil organisms we must first acquaint ourselves with the structure and classification of those existing forms to which the fossils we desire to examine are most closely related. Unless this plan is adopted the study of fossils cannot be attended with much practical good.

This principle cannot be too strongly enforced on those who are beginning the study of palæontology, for most of the errors and misinterpretations of fossil remains, which form a blot on much palæontological work, have arisen from the neglect of this precaution alone.

In my remarks on the structure and classification of recent ferns I shall be as brief as possible, and I shall only enter on those points which are necessary for an intelligent appreciation of the points of agreement and difference between recent and fossil genera and species.

FILICACEÆ.

Ferns are classified in accordance with the manner in which the *sporangia* are developed. Looked at from this structural point ferns fall naturally into two divisions :—

A. LEPTOSPORANGIATE FILICACEÆ.

Ferns in the more restricted sense of the word; sporangia formed from a single epidermal cell, and provided with an *annulus*.

This division is further separable into—

I. Homosporous Filicaceæ.

II. Heterosporous Filicaceæ.

I. Homosporous Filicaceæ.

Here, as the name implies, the spores are of one kind. The ferns in this group may have more or less developed upright undivided stems, or the stems may be decumbent and divided. The fronds are extipulate, circinately rolled up when young, and bear sporangia which are usually developed on some part of the veins at the back of the frond, but may be developed from the mesophyll or ground tissue of the frond. The sporangia are rarely borne on both sides of the frond (*Olfersia*). They may be sessile or stalked, and usually form groups termed *sori*, which are naked, or covered with a scale-like structure called an *indusium*. The part of the vein which bears the *sorus* is often thickened and more or less elevated, and so forms a *receptacle* or *placenta*.

The sporangia of this division of ferns are small roundish capsules, with a stalk in the Polypodiaceæ and Cyatheaceæ, but generally sessile in the others. The wall of the mature capsule is formed of one layer of cells, and a row of cells in this layer is developed in a peculiar manner and forms the *annulus*. (Plate I., figs. 1-6.) The annulus may take a transverse or oblique course across the sporangium, or form an upright band.

Sometimes the annulus is developed as a lateral group of cells, or forms an apical cap. The cells of the annulus are usually prominent and conspicuous.

The contraction of this structure at maturity, caused by the drying of the sporangium, bursts the capsule at right angles to the plane of the annulus.*

The position and structure of the annulus form an important character in the classification of the *Leptosporangiate* ferns.

The Homosporous Filicaceæ contain six families :—

Family 1.—Hymenophyllaceæ. (Plate I., fig. 1.)

The sporangia have an oblong or transverse complete annulus, and open by a longitudinal fissure. They are borne on a prolongation of the fertile vein,—the columella or placenta, which projects beyond the margin of the leaf, and is surrounded by a cup-shaped indusium. Sporangia sessile except in *Loxsoma*, where they are stalked.

* The bursting of the sporangia is accompanied by a little jerk, which assists in the dissemination of the spores.

Family 2.—Cyatheaceæ. (Plate I., fig. 2.)

The sporangia have a short stalk and a complete oblique eccentric annulus. They are placed on a placenta, which is often greatly developed, and form a sorus which is usually closely packed, and is either naked or surrounded by a cup-shaped indusium which sometimes forms a closed capsule.

Family 3.—Polypodiaceæ. (Plate I., fig. 3.)

Sporangia with a vertical incomplete annulus; numerous, placed on the veins or on the mesophyll on the under side of the usually unaltered fronds, rarely on both surfaces of the frond *(Acrosticheæ)*, naked or indusiate.

Family 4.—Gleicheniaceæ. (Plate I., fig. 5.)

Sporangia sessile, usually 3-4 in a sorus on the dorsal surface of the ordinary leaves; annulus transverse and complete.

Family 5.—Osmundaceæ. (Plate I., fig. 4.)

Sporangia arranged in panicles and placed on the laciniæ of leaves that have no mesophyll *(Osmunda)* or the fertile leaves resemble the sterile *(Todea)*. Sporangia of unsymmetrical roundish form on short stalks; annulus on one side near the apex and composed of a group of peculiarly formed cells.

Family 6.—Schizæaceæ. (Plate I., fig. 6.)

The laciniæ that bear the sporangia arranged in spikes or panicles, or on the under surface of the frond near the margin, which is turned back over them; sporangia ovoid or pear shaped; annulus composed of peculiarly formed cells surmounting the sporangium like a cap.*

II. Heterosporous Filicaceæ, or Hydropterideæ.

This latter division includes the Salviniaceæ and Marsileaceæ, in whose sporangia are contained macro- and microspores, but as it is not my intention to consider the fossil allies of these plants this evening, we shall not enter into their structural peculiarities.†

* It is almost unnecessary to mention the names of the works containing fern classification, as it is given in all the better text-books, but the two following may be specially noted:—"Outlines of Classification and Special Morphology," Goebel; and "Comparative Anatomy of the Phanerogams and Ferns," De Bary. (English editions.)

† Dawson, "On Rhizocarps in the Erian (Devonian) Period in America." *Bull. Chicago Acad. of Science*, vol. i., no. 9, 1886, p. 105.

B. EUSPORANGIATE FILICACEÆ.

In these ferns the sporangia proceed from a group of cells. The species are all *homosporous*, and the sporangia *exannulate*. As a number of the Carboniferous species, of which the fruit is known, belong to this group of ferns—a group which is but feebly represented in recent times when compared with their palæozoic ancestors—it is necessary that the fructification of the recent genera be carefully considered.

This division contains two orders :—

I. MARATTIACEÆ, and II. OPHIOGLOSSACEÆ.

Order I.—MARATTIACEÆ comprises the five following genera :—

a. Marattia, Sm.
b. Eupodium, Sm.
c. Angiopteris, Hoffm.
d. Danæa, Sm.
e. Kaulfussia, Blume.

a. Marattia, Sm. (Plate I., fig. 7.)—Synangia* sessile, superficial, oblong, distant, sub-terminal, longitudinally bivalved, each valve consisting of 3-12 laterally connate thick-walled sporangia. The sporangia are narrow-cordate, acute, and open by a slit on their inner side.

In the earlier stages of development the two inner sides of the valves of the synangium are adpressed face to face, but towards maturity the valves separate and bend backwards and outwards. The fronds are from 6-18 feet long.

b. Eupodium, Sm.—The synangia are similarly formed to those of *Marattia*, but are pedicellate.

c. Angiopteris, Hoffm. (Plate I., fig. 8.)—Receptacles oblong, linear, obovate retuse; sporangia biserial, thick-walled, sessile, free, contiguous, opening by a slit on the inner side; sori oblong, laterally contiguous, forming a broad sub-marginal transverse band.

d. Danæa, Sm. (Plate I., fig. 9.)—Synangia sessile, immersed, linear, contiguous, occupying nearly the whole length of the venules and covering the whole under surface of the fertile fronds; each synangium consists of two rows of numerous laterally and oppositely connate obliquely oval sporangia, forming a concrete mass; each sporangium opens by an apical circular pore. Fronds 1-3 feet long.

* When the sporangia are united to each other, the term *synangium* is applied to the structure.

c. Kaulfussia, Blume. (Plate I., fig. 10.)—Synangia sessile, superficial, orbicular, concave-hemispherical, each consisting of 10-20 clavate sporangia laterally connate in a circular series and opening by a slit on their inner side.

In the Marattiaceæ the sporangia are formed of several layers of cells and the base of the frond bears two lateral fleshy stipulæform appendages, with the exception perhaps of some species of *Danæa*.

Order II.—Ophioglossaceæ. This order contains three genera:—

a. Ophioglossum, Linn.
b. Helminthostachys, Kaulf.
c. Botrychium, Linn.

a. Ophioglossum, Linn.—Fructification in a distichous spike, terminating a distinct branch of the frond, or on a distinct frond. The sporangia form cavities in the tissue of the fertile portion of the frond and on its lateral faces, but somewhat nearer to one margin. Dehiscience by a transverse slit.

b. Helminthostachys, Kaulf.—Fructifications consisting of glomerate verticillate tufts of sporangia, the whorls terminated by a crest-like appendage and arranged in distichous spiked panicles on a distinct branch of the frond. Sporangia fleshy, coriaceous, globose, sessile, inverse, bursting on the outer side from the base upwards into equal or sub-equal hemispherical valves.

c. Botrychium, Linn.—Fructifications paniculate, formed of numerous secund spikelets on a distinct branch of the frond, sporangia erect, sessile, free, biserial, fleshy, coriaceous, bursting vertically into two equal hemispherical valves.

As none of the fossil fructifications which I wish to bring before you have any close affinities with the Ophioglossaceæ, this order may be passed over for the present.

Development and Arrangement of the Parts of the Frond.

The fern frond may be simple, as is the common Hart's tongue *(Scolopendrium vulgare)*, or variously divided. Among these latter a pinnate arrangement is perhaps the most prevalent. Here the frond appears as if it possessed a continuous growing axis, from which are given off in one plane opposite or alternate branches *(pinnæ)*. Such an appearance is, however, entirely deceptive, as the fronds of ferns divide by a series of dichotomies, but one of the forks of each dichotomy is usually arrested in its development.

First let us examine a case of simple dichotomy. Here the growing point divides into two equal arms; each of these arms again divides and produces branches of the second degree. This process is repeated till there is produced a very complex series of ramifications of different degrees, each succeeding series or generation containing twice as many branches as that which preceded it. This form of ramification is characteristic of the *vascular cryptogams*, and is well seen in *Lycopodium* and *Selaginella* among recent genera, and in the fossil genera *Lepidodendron* and *Bothrodendron*.

Now let us suppose that the further development of one of the two arms of each dichotomy is arrested and repeats no further dichotomies, but that the other arm divides again. Let one of the arms of this last fork dichotomise, but let the further development of the other corresponding arm be suppressed, and if the forks in which further development has been arrested be situated alternately to the right and left of the axis, they are thrown aside by the stronger growth of their corresponding arms which have continued to dichotomise. Thus results the apparently pinnate arrangement of the pinnæ on fern fronds, and though they possess all the appearance as if the pinnæ were developed laterally from a continuous axis, the axis of a fern frond is in reality compound, and its component parts belong to different and successive dichotomies—the various portions of the axis representing in fact the arms of the dichotomies which have further divided. Such is the explanation of the ramification of most fern fronds.*

There is another form of sympodial ramification which occurs in ferns, being produced when the non-developed arms of the dichotomy are all placed on one side of the rachis. This results in the rachis being more or less curved or bent, and has been distinguished as *bostrychoid* dichotomy. This form of *sympodial* dichotomy occurs in *Adiantum pedatum*.

An equal dichotomy takes place in the fronds of a few ferns, such as *Actiniopteris radiata* and *Rhipidopteris peltata*, but by far the commonest form is that which produces the pinnate appearance and has been named *cicinnal* dichotomy.

There is still one point to which I would like to call your attention before leaving this subject.

* Called cicinnal dichotomy.

The growth of the fern frond is strictly *basifugal* or *apical*, in consequence of which the lower pinnæ may be fully developed while the apex of the frond still continues to produce new pinnæ. In some species, after the first pair of pinnæ are developed, the further growth of the frond comes to a standstill, and the apex of the frond remains as a bud between the forks of the two pinnæ. At a subsequent period the bud may continue its development, but frequently it proceeds no further, as in many *Gleichenia* and *Mertensia*, where the fronds appear as if formed from a series of true dichotomies; but here again there is merely an example of cicinnal dichotomy simulating true dichotomy, which is brought about by the arrested development of the growing point.*

From the bud in the forks of the pinnæ of *Mertensia* there may be produced a few irregular frondose growths as in *M. (Gleichenia) gigantea*, Wall.†

Forked or tasselled varieties of ferns, usually the result of cultivation, are formed by a series of equal dichotomies of the growing points of the pinnæ or apex of the frond.

Let the ramification of Carboniferous fern fronds now be looked at, and as the structural points of those of recent ferns have been so fully considered, it may be done very shortly. One point that cannot fail to strike the botanist in regard to this is the much more common occurrence of equal dichotomy. The fossil specimens usually met with do not show this, for even the larger and more perfect examples generally represent only one arm of the dichotomy. Among the Sphenopteroids a dichotomous ramification is frequent, either of the main rachis or of the secondary rachis. I should perhaps say here that the genus *Sphenopteris*, as constituted and employed by Brongniart and subsequent writers till within the last few years, comprised ferns evidently belonging to many different genera; but from the absence of any knowledge of their fruit, it seemed advisable to make its generic characters very wide, as it is all but impossible to found satisfactory and restricted genera from characters derived from the nervation alone. It must therefore be regarded rather as a group

* Several of the figures of *Gleichenia* in Hooker's "Species Filicum," vol. i., show this. Many species of the genus are in cultivation, and can be easily studied.

† Hooker, "Species Filicum," vol. i., plate iiiA.

than as a true genus. Of many of these Sphenopteroids the fructification has been discovered, and as this character becomes known new genera founded upon the fructification are formed for the reception of these fruiting species.

In some of the species of *Calymmatotheca (Sphenopteris)* the main rachis apparently forms a true dichotomy, each limb of which bears the alternate lateral pinnæ. In certain other species the main rachis gives off naked alternate secondary raches which bifurcate, and on the bifurcations are the foliage-bearing pinnæ. Dr. Stur * has formed the genus *Diplothmema* for these Sphenopteroids. In another group of ferns, some of which were formerly placed in *Sphenopteris* and others in *Pecopteris*, the main rachis bears alternate naked secondary raches which bifurcate in an open angle and each of the resulting arms again bifurcate, and on these latter are borne the foliage-bearing pinnæ. Zeiller has applied the name of *Mariopteris* to these ferns.† Both *Diplothmema* and *Mariopteris* contain many British species. As an example of the former *Sphenopteris furcata* may be mentioned, and of the latter *Pecopteris muricata*.

These two genera are not altogether satisfactory, for their fructification is unknown. In regard to *Diplothmema*, it is founded on an *additional* character to those formerly known to occur in *Sphenopteris*, and the genus is therefore, according to my view, utterly untenable. With respect to *Mariopteris* for one of the species included in it, *M. muricata*, although its fruit is unknown, the genus is desirable, for the nature of the plant and the texture of the pinnules separate it at sight from all other species, but for all or most of the other members of the genus I think they should be retained in *Sphenopteris*.

A dichotomous ramification of the pinnæ (apparently brought about by the arrested development of the growing point), and the fructification of *Pecopteris Pluckenetii*, Sternb., have been described by Sterzel,‡ who has proposed for this fern the generic name of *Dicksoniites*.

The presence of an undeveloped bud between the forks of the pinnæ of *Gleichenia* has been already referred to, and a similar undeveloped bud has been observed in a like position in *Dick-*

* Stur, "Die Culm Flora," heft ii., 1877, p. 233.

† Zeiller, *Bull. Soc. Géol. de France*, 3e sér., 1879, vol. vii., p. 92.

‡ Sterzel, *Botanisches Centralblatt*, no. 8/9, 1883, plate vi.

soniites and *Sphenopteris (Diplothmema) subgeniculata*, Stur.* Both of these are British species.

In regard to generic characters derived from the bifurcation of the pinnæ, it may be mentioned that in *Gleichenia (Mertensia)* the pinnæ of the frond are sometimes formed of one, at other times of two pairs of forks.

The pinnæ of certain species of the common Carboniferous genus *Neuropteris* appear to have dichotomised several times.

In recent ferns, in addition to the rachis frequently bearing scales, the upper and lower surfaces of the pinnules also occasionally bear hairs or scales, as in *Ceterach officinarum*. Among fossil species the same structures are found. The rachis of many palæozoic species has been more or less densely covered with scales, and in many species of *Pecopteris*, of the *P. arborescens* group, the upper surface of the pinnules is covered with a dense clothing of hair which imparts a velvety appearance to it. So dense is this covering in some cases that it entirely obscures the veins.

In *Neuropteris Scheuchzeri*, Hoffm., *N. horrida*, Zeiller, and some other members of the genus, the upper surface of the pinnules also bears hairs. On some Sphenopteroids the same character is seen.

Arrangement of Veins and Pinnules.

The veins in the pinnules of both recent and palæozoic ferns are most diversified in their arrangement—the chief modes of arrangement occurring alike in both.

The veins may radiate fan-like from the base of the pinnule, or a main vein may give off lateral simple, or more or less dichotomised veinlets, or the veinlets may anastomise and form a network *(Dictyopteris* and *Lonchopteris)*. The pinnules are stalked, or united by their whole base to the rachis, and may further be united among themselves to a greater or lesser extent, and decurrent on the rachis, which in turn may be winged. As one or more of these different forms of nervation may occur among recent ferns in one and the same genus, the character of the nervation alone is of little value for a satisfactory generic distinction. A slight examination of recent genera will show how the nervation varies in certain genera, and, further, how it varies on different parts of the same frond.

* Stur, "Culm Flora," p. 241, plate xxix., fig. 8.

Notwithstanding this, by far the greater number of palæozoic ferns are classified from characters derived from the nervation, coupled, however, with the form of the pinnules and their mode of attachment to the rachis. From this it will be seen that much of this classification is provisional; but, while recognising the great disadvantage under which the palæo-botanist works, experience has shown that many of the fossil genera founded on the characters just mentioned are so well characterised, that probably, in some cases at least, they form natural groups. The venation, however, forms undoubtedly one of the best characters for discriminating fossil species, but it requires a little experience to distinguish real differences, for the nervation of the pinnules, situated towards the apex of the pinnæ, is generally slightly different in detail from that of the pinnules placed towards their base.

To sum up this part of our comparison of Carboniferous with recent ferns, it will be seen, in regard to the ramification of the frond, that the same laws which regulate the development of the fronds of existing species also controlled the growth of those of Carboniferous times, though dichotomous ramification of the frond appears to have been much more frequent in palæozoic times than at present.

In some cases the apparently equal dichotomy in palæozoic species *may* have arisen from an arrested development of the growing point, as in *Gleichenia* and *Mertensia*, whilst at other times it seems to be a case of true equal dichotomy.

Aphlebia.

On certain recent ferns, as at the base of the rachis of *Alsophila (Hemitelia) capensis*, J. Sm., there are developed what may be called abortive pinnæ, about 3-4 inches long, many times multifid, with narrow linear membranous segments and a rigid costa. These at first sight resemble a *Trichomanes* or *Hymenophyllum* in a barren state, growing parasitically on the *Alsophila*, and Kaulfuss has described these abortive pinnæ under the name of *Trichomanes* (?) *cormophyllum*. (Hooker. "Species Filicum," vol. i., p. 37.) Also in *Gleichenia gigantea*, Wall., a collection of leafy, deeply laciniate persistent scales arises at the base of the primary pinnæ.

Among fossil ferns the development of similar Aphlebia are of

even more frequent occurrence, and though many of these so-called Aphlebia have been found attached to fronds and are undoubtedly an integral part of them, there are other allied fossils of large size, regarding which I am not quite sure that they do not form individual species. Of such is the *Rhacophyllum (Schizopteris) lactuca*, Sternb., sp., and allied forms.

With those Aphlebia, however, which must be classed as an integral part of the frond on which they occur, *Schizopteris adnascens*, L. and H.,* must be included. This was originally supposed to be a distinct species of climbing fern which had twined up the rachis of *Sphenopteris crenata*, L. and H.

SECTION II.

DESCRIPTIONS OF THE FRUCTIFICATION OF CARBONIFEROUS FERNS.

A. SPORANGIA PROVIDED WITH AN ANNULUS.

Isolated *annulate sporangia* are not of uncommon occurrence at those localities in Britain which yield fossil plants with their internal structure preserved, as at Pettycur, Fife (Calciferous Sandstone series), and the Yorkshire and Lancashire coal fields. (Plate I., figs. 11, 12, 13.)

In all structural points many of these sporangia are individually identical with those of recent annulate sporangia, in their wall being composed of a single layer of cells, certain of these being enlarged to form the annulus; but in all cases where the sporangia have been found in position on the fronds, the position of the annulus and the arrangement of the sporangia are apparently different from that of the sporangia of any existing genus.

Hymenophyllites, Göppert, 1836.

(Plate I., fig. 14.)

Hymenophyllites, Göppert, "Syst. Fil. Foss.", p. 251.
,, Zeiller, *Ann. d. Sci. Nat.*, 6e sér., Bot., vol. xvi., p. 195.
,, ,, "Flore foss. d. bas. houil. d. Valen.", p. 56, fig. 36. (*H. quadridactylites*, Gutbier, sp.)

Description.—Fructification resembling that of *Hymenophyllum*; sporangia pyriform, pointed at the base, provided with a complete transverse annulus and placed at the extremities of the lobes of the pinnules.

* Lindley and Hutton, "Fossil Flora," vol. ii., plate c., ci.

Remarks.—The actual presence of a column to which the sporangia were attached has not yet been observed, but the manner in which the sporangia are placed on the specimen of *Hymenophyllites quadridactylites*, Gutb., sp., figured by Zeiller,* points very strongly in favour of the view that the sporangia had originally been attached to a column, for they are occasionally arranged in two slightly irregular parallel rows, continued outwards from the extremity of the pinnule, and having between them a clear space which looks as if it had originally been occupied by some structure that has now disappeared. Although the species included in *Hymenophyllites* cannot, from what we know of their fructification, at present be referred to the genus *Hymenophyllum*, there is still sufficient evidence to show that during Upper Carboniferous times, there existed a *genus* of ferns closely related to *Hymenophyllum*, and though it cannot be said with certainty that these ferns belong to any existing genus, they can however be placed in the Hymenophyllaceæ.

The only claim Britain has to *Hymenophyllites*, as far as I am aware, is founded on the occurrence of a small barren specimen of *Hymenophyllites quadridactylites*, Gutb., sp., from the "Ten-feet Ironstone Measures," Coseley, near Dudley (Middle Coal Measures), which has lately been submitted to me for examination by Mr. Herbert W. Hughes, F.G.S.†

Oligocarpia, Göppert, 1841.

(Plate I., fig. 15.)

Oligocarpia, Göppert, "Gatt. d. Foss. Pflanzen," lief. 1 and 2, p. 3, plate iv., figs. 1 and 2 (*O. Gutbieri.*)

,, Zeiller, *Ann. d. Sci. Nat.*, 6e sér., Bot., vol. xvi., p. 190, plate x., figs. 6-15.

,, Zeiller, "Flore foss. d. bas. houil. d. Valen.", p. 53, fig. 35.

,, Schimper, "Traité d. Paléont. Végét.", vol. i., p. 585, plate xli., figs. 8-9.

Renault, "Cours d. Botan. Foss.", 3e an. (1883), p. 67, plate vii., figs. 1 and 3.

* *Loc. cit.*, *Ann. d. Sci. Nat.*, and "Flore foss. d. bas. houil. d. Valen."

† In studying the Carboniferous Hymenophyllaceæ we must dismiss from our minds the *Hymenophyllum Weissii*, Schimper ("Traité d. Paléont. Végét.", vol. i., p. 246, plate xxviii., figs. 4-7), from the Coal Measures of Saarbrück, for according to Solms-Laubach the figures and description of this fossil are inaccurate. (Einleitung in die Paläophytologie vom botanischen standpunkt, 1887, p. 157.)

Description.—Sporangia pyriform, in number from 3-10 attached by their narrow extremities to the summit of the fertile veins, and placed on the limb in a "rose-like" heap, thus forming a circular, or sometimes hemispherical sorus, in which case some of the sporangia in the centre of the group stand erect. The sporangia are provided with a complete transverse annulus formed of one row of cells.

Remarks.—When the sporangia are viewed laterally, the position in which those which occupy the lowest and outermost circle of the sorus are seen admits of the annulus only being seen on their external face, its continuation being hidden beneath; but when the sporangia are viewed from above, as those in the centre of the sorus may be, the annulus is seen to form a complete circle.

The structure of the fruit of the *Oligocarpia* presents therefore a complete identity, as well in the structure of the individual sporangia as in their arrangement into sori, with that of *Gleichenia*. It is true that the ramification of the fronds of *Oligocarpia* and *Gleichenia* differ much. In the former the regular pinnate fronds do not show any similarity to the dichotomously-like divided fronds of *Gleichenia* (through non-development of the growing point), but in the more important character of fructification *Oligocarpia* and *Gleichenia* possess sporangia so similar in structure and arrangement that there can remain no doubt as to the true position of *Oligocarpia* being in the Gleicheniaceæ.

The only species of the genus I have yet seen in Britain is *Oligocarpia Brongniarti*, Stur, which was collected by Mr. W. Hemingway in shale over the "Barnsley Thick Coal," at Woolley Colliery, Darton, near Barnsley. (Middle Coal Measures.)

Senftenbergia, Corda, 1845.

(Plate II., fig. 16.)

Senftenbergia, Corda, "Beitr. z. Flora d. Vorwelt," p. 91, plate lvii., figs. 1-6.

,, Zeiller, "Flore foss. d. bas. houil. d. Valen.", p. 50, fig. 34 (*S. elegans*, Corda).

,, Zeiller, *Ann. d. Sci. Nat.*, 6e sér., Bot., vol. xvi., p. 188, plate x., figs. 1-5 (*S. elegans*, Corda).

,, Schimper, "Traité d. Paléont. Végét.", vol. i., p. 578, plate xli., figs. 4-7.

Description.—Sporangia ovoid, pointed at the summit, sessile, arranged in two parallel series, one on each side of the medial vein,

provided with an apical conical cap-like annulus, which occupies about two-fifths of the height of the sporangia, and formed of many rows of thick-walled cellules: dehiscing by a longitudinal split, which is directed towards the margin of the pinnule.

Remarks.—A line of narrow cells extends, apparently from the apex to the base of the sporangium, at which part the sporangia burst at maturity. The dehiscence is brought about by the contraction of the apical annulus, as in the Schizæaceæ.

Though the position of the annulus in *Senftenbergia* is similar to that in the Schizæaceæ, in *Senftenbergia* it is composed of several rows of cells, whereas in the Schizæaceæ (of which the chief genera are *Schizæa*, *Aneimia*, *Lygodium* and *Mohria*), it is composed of a single row of cells which are much elongated vertically.

In the closely allied tribe Osmundaceæ, the annulus does not completely encircle the sporangia, but forms a patch composed of several rows of polygonal cells. *Senftenbergia* agrees, therefore, in the several "cell-rowed" structure of the annulus with the Osmundaceæ, but differs in the annulus forming a complete cap. With the Schizæaceæ it agrees in the annulus forming a *complete cap*, but differs in the cap being composed of several rows of cells. The difference, however, between the sporangia of *Senftenbergia* and those of Schizæaceæ is very slight, so slight that I believe *Senftenbergia* should be placed in the same tribe. I am not aware that *Senftenbergia* has yet been observed in Britain.

Corynepteris, Baily, 1860.

(Plate II., fig. 17.)

Corynepteris, Baily, "Explan. to sheet 142, Geol. Surv. Ireland," p. 16.
,, Baily, *Nat. Hist. Rev.*, vol. vii., p. 258, plate xiv.
,, Zeiller, "Flore foss. d. bas. houil. d. Valen.", p. 41, fig. 28.
Grand 'Eurya, Zeiller, *Ann. d. Sci. Nat.*, 6e sér., Bot., vol. xvi., p. 203.
Saccopteris, Stur, "Zur Morph. und Syst. d. Culm u. Carbon Farne," p. 64.
,, Stur, "Carbon Flora," vol. i., p. 159.
Grand 'Euryella, Weiss, *Neues Jahrb. fur Miner.*, 1885, vol. i., p. 492.

Description.—Fertile pinnæ similar to the sterile, or the limb of the pinnules more or less reduced; sporangia of large size, ovoid, sessile, provided with a complete longitudinal annulus formed of many rows of cells. Sporangia grouped to the number of from 5-10 around the same point, forming by their union a spheroidal

sorus—the sporangia touching each other by the edges of their annuli which encompass their dorsal aspect.

Remarks.—The sori appear to be situated on the medial nerve towards the base of the fertile pinnule. Owing to differences in their preservation, the sori are sometimes flattened, and the component sporangia appear triangular, and arranged star-like round a common point of attachment, the annulus forming rays diverging from the centre: sometimes the sori are flattened laterally and lie parallel with the pinnule, and the sporangia being close together the sorus looks like a small melon. Occasionally all these conditions are found on one and the same pinna. The annulus is formed of several rows of thick-walled cells which are broader than long, whilst those on the other parts of the sporangia are longer than broad and with thinner walls.

Towards the base of the sporangia the cells of the annulus become less and less differentiated from those of the walls, and finally assume the same aspect.

These sporangia in their general structure closely resemble those of *Zygopteris* (to be presently described), and might be easily mistaken for them.

In *Zygopteris*, however, the sporangia are clearly pedicellate, less regularly grouped, and generally do not touch each other by their annuli, and they never show in imprints a star-like grouping which is so often observed in *Corynepteris*, and, finally, in *Zygopteris* the fertile pinnules are entirely deprived of the limb.

Corynepteris and *Zygopteris* belong to a group whose fructification separates them altogether from any existing genera.

This genus was described by Baily from a specimen procured by Mr. G. H. Kinahan from the old collieries near Glin, in the townland of Ballygiltenan Lower, County Limerick. I have also met with the genus in the South Wales and English coalfields.

Renault includes *Zygopteris* and one or two allied genera in a group which he has named "Botryopterideæ." Recent investigation necessitates, however, a slight modification of the characters of this group as defined by him. ("Cours d. Botan. Foss.", 3e an., p. 100, 1883.)

Zygopteris, Corda, 1845.

(Plate II., fig. 18.)

Zygopteris, Corda, "Beitr. z. Flora d. Vorwelt," p. 81.
,, Renault, *Compt. Rend. Acad. Sci.*, vol. lxxxii., p. 992.
,, ,, *Ann. d. Sci. Nat.*, 6e sér., Bot., vol. iii., p. 5.
,, Zeiller, "Flore foss. d. bas. houil. d. Valen.", p. 46, fig. 30 *(Z. pinnata)*.

Description.—Fertile pinnules deprived of the limb; sporangia of large size, ovoid, much longer than broad, tapering into a pedicel at the base, and united from 5-15, or perhaps more, to the extremity of a common peduncle; sporangia often a little arched and provided with a complete longitudinal annulus formed of many rows of cells.

Remarks.—This genus was founded by Corda for fossil fern petioles or fragments of the rachis, having the vascular system in the form of a *double-anchor*, and Renault has been successful in finding some sporangia attached to a fern stem which possessed all the characters of the genus *Zygopteris* of Corda. These specimens described by Renault were preserved in silica and exhibited the minute structure of the sporangia. According to him the wall of the sporangium is formed of several rows of cells, in the interior of which is a very delicate membrane, contracted and separated from the external wall, and in this were contained numerous smooth spores. The wall of the sporangium being composed of more than one series of cells, and having in addition a very prominent and clearly differentiated compound annulus, shows that *Zygopteris* is distinctly separated from all recent genera of ferns. (Zeiller, *op. cit.*, p. 46.)

Schizostachys, Grand 'Eury, 1877.

(Plate II., fig. 19.)

Schizostachys, Grand 'Eury, "Flore Carbon. du Départ. de la Loire," p. 200.

Remarks.—This genus is probably identical with *Zygopteris*. It was characterised by Grand 'Eury as having oblong, slightly curved pedicellate sporangia, attached around a common point or on the sides of a common pedicel. The sporangia wall is thick and complex, and is composed of two layers—the external cellular, the inner fibrous.

The British specimen I refer to this genus was collected at Radstock from the Radstock series of the Somerset and Bristol coal-field.*

The internal structure of the sporangia of my example is not preserved, it being merely an impression, but the outer surface of the oblong sporangia, which are usually developed in pairs on a bipinnate frond (?), shows a longitudinal line from which extend on each side fine transverse bars. This vertical series of transverse bars may, I think, be the annulus, but owing to the specimen not showing all the characters necessary for a satisfactory determination of the generic position of the fossil, its true position is somewhat doubtful. I have placed it, provisionally, in *Schizostachys*, under the name of *S. sphenopteroides*.

B. SPORANGIA EXANNULATE.

Scolecopteris, Zenker, 1837.

(Plate II., fig. 20.)

Scolecopteris, Zenker, *Linnæa*, vol. xi., p. 509.
,, Schimper, "Traité d. Paléont. Végét.", vol. i., p. 680.
,, Zeiller, "Flore foss. d. bas. houil. d. Valen.", p. 39, fig. 25.
Acitheca, Schimper, "Handb. d. Palæont.", vol. ii., p. 91.

Description.—Fertile and barren pinnules similar, or the limb of the fertile pinnules only slightly reduced, and the margin often rolled backwards. The sporangia taper at the summit to a sharp point, and are united to the number of 4-5 around a very prominent receptacle. Each group thus forms a pedicellate synangium normally standing erect from the limb.

Remarks.—This genus differs from *Asterotheca* (next to be described), in the sporangia ending in a long tapered point, and in the synangia being pedicellate. When found as impressions the synangia are usually flattened, giving the pinnules the appearance as if covered with stiff bristles.

According to the investigations of Renault ("Cours d. Botan. Foss.", vol. iii., p. 116, plate 20, figs. 7-10), the receptacle contained 4-5 prominent ridges, being in transverse section stellate, and to each ridge was attached the inner surface of one of the sporangia.

The wall of the sporangium is formed of several layers of thick-walled cells, except on the side by which they are attached to the receptacle, where the thick wall is not developed, and its place

* *Trans. Roy. Soc. Edin.*, vol. xxxiii., p. 352, plate xx., fig. 1.

is taken by a thin partition of delicate cells. At maturity the sporangia open by a longitudinal slit which passes through the line of this delicate membrane.

The only species of *Scolecopteris* occurring in Britain is *S. polymorpha*, Brongt., sp., which is found in the Upper Coal Measures.

Asterotheca, Presl., 1845.

(Plate II., fig. 21.)

Asterotheca, Presl. in Corda, "Beitr. z. Flora d. Vorwelt," p. 89.
,, Zeiller, "Flore foss. d. bas. houil. d. Valen.", p. 36, figs. 23 and 24.
Asterocarpus, Göpp. (*not* Necker, Ecklow, nor Zeyher), "Syst. Fil. Foss.", p. 188.
Hawlea, Corda, "Beitr. z. Flora d. Vorwelt," p. 89, plate lvii., figs. 7 and 8.
Grand'Eurya, Stur (*not* Zeiller), "Zur Morph. und Syst. d. Culm u. Carbon Farne," p. 45.
Scolecopteris, Stur (*in part*), ibid., p. 88.

Description.—Fertile pinnules similar to the barren or the limb, only little reduced; sporangia ovoid, acute or slightly obtuse at the summit, united to the number of 4-5, rarely more or less, around a very slightly elevated receptacle, each group thus constituting a sessile synangium, which in the normal condition stands erect.

Remarks.—The synangia are attached to the secondary veins, sometimes near the base, sometimes near their centre, more rarely at their extremity close to the margin of the pinnule.

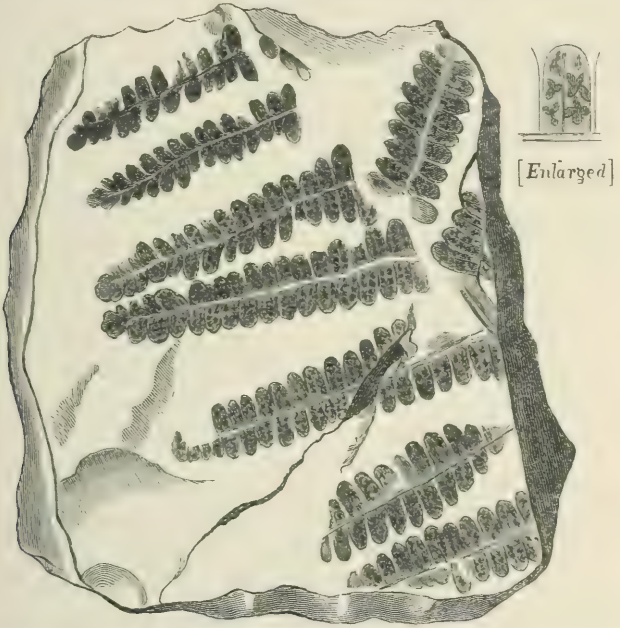
The sporangia which constitute the synangia are usually equally developed, but in some species those sporangia of the group that form the side of the synangium next to the margin of the pinnule are more developed and larger than those next to the midrib of the pinnule. Most commonly each pinnule bears two parallel series of synangia—one on each side of the medial nerve. Sometimes, however, on large pinnules which are probably composed of smaller pinnules united by their margins, one sees on each side of the central vein two parallel series of synangia. This has been observed in *Pecopteris oreopteridia*, Schl., sp., and *P. Miltoni*, Artis, sp.

The receptacle around which the sporangia are attached appears to have been more or less elevated according to the species, without, however, attaining a height equal to that of the sporangia them-

selves, which remain always free at the summit and without doubt throughout a great part of their height.

It would appear from the researches of Grand 'Eury* and Renault† that the sporangia at maturity open by a vertical longitudinal cleft.

In the earlier stages of the development of the synangia of *Asterotheca*, the sporangia are erect and closely adpressed against each other, but towards maturity they separate and become bent back on the limb of the pinnule, forming a star-like group.



Pecopteris Miltoni, Artis., sp. (=*Hawlea pulcherrima*, Corda), Forest of Wyre, Worcestershire. In the Collection of the British Museum.

A very similar sequence of developmental stages is seen in *Marattia*. At first the two rows of the oval synangia are closely adpressed to each other by their inner surfaces, but towards maturity the two rows begin to separate from each other, and at length those surfaces which originally pressed upon each other are eventually directed outwards and upwards in a line almost

* "Flore Carbon. du Départ. de la Loire," 1877.

† "Cours de Botan. Foss.", 3e an., Fougères, 1883.

horizontal with the surface of the pinnule.* Dehiscence takes place here also through a longitudinal ventral cleft.

In *Marattia* the sporangia are laterally united throughout their whole length and form two opposite parallel rows, which are united at their extremities—thus forming an oval synangium. In *Asterotheca* the sporangia are only united at their base, are much fewer in number in each synangium, and are arranged in the form of a star.

Asterotheca has also affinities with *Kaulfussia*. In the latter the sporangia, by complete union round a common circular receptacle, form cup-like synangia. If then we imagine the sporangia separated from each other, except at their basal extremity, we should have an arrangement of synangia similar to that which occurs in *Asterotheca* at maturity.

Asterotheca differs chiefly from *Scolecopteris*, to which it is closely related, by its having short capsules, and in the synangia not being pedicellate, or only very slightly so.

All the members of the genus *Asterotheca* at present known belong to the genus *Pecopteris*, Brongt. They are characteristic of the Upper and Middle Coal Measures, and many of them occur in England, as *P. arborescens*, *P. oreopteridia*, &c.

Asterotheca and *Scolecopteris* are clearly Marattiaceous, but could not be placed in any existing genus.

Ptychocarpus, Weiss, 1869.

(Plate II., fig. 22.)

Ptychocarpus, Weiss, "Foss. Flora d. jüngst. Stk. u. d. Rothl.", p. 94.
,, Zeiller, "Flore foss. d. bas. houil. d. Valen.", p. 40, fig. 26.
Stichopteris, Weiss, "Foss. Flora d. jüngst. Stk. u. d. Rothl.", p. 96.

Description.—Fertile and sterile pinnules similar, sporangia almost cylindrical, very slightly tapered at the summit, from 5-8 surrounding a very prominent receptacle to which they are united in all their length and attached to each other by their lateral faces.

Remarks.—The synangia are sometimes disposed in two parallel rows on each pinnule, sometimes in many rows on the large compound pinnules—to the number of four on each side of the medial nerve. As the synangia stood up prominently from the surface of the pinnules, in consequence of pressure they are often bent over on the veins.

* See plate i., fig. 7, *Marattia*.

M. Renault has shown, from the examination of a silicified specimen, that the sporangia which compose the synangia are completely united among themselves to a central receptacle into which extends an axile vascular bundle.*

This type of fructification has only been observed in certain Pecopterids of the Upper Coal Measures, which belong to the group of *Diplazites*, Göppert; but as this genus has been founded on characters derived from the nervation, and probably contains other types of fructification than that just described, it cannot be employed for those species which are generically distinguished by the structure of the fruit.

Ptychocarpus unitus, Brongt., sp., is frequent in the Upper Coal Measures of England.

Calymmatotheca, Stur, *emend.*, 1877.

(Plate II., fig. 23; Plate III., fig. 37.)

Calymmotheca, Stur, "Culm Flora," vol. ii., p. 255 (*in part*).
,, ,, "Zur Morph. u. Syst. d. Culm u. Carbon Farne," p. 167 (*in part*).
,, ,, "Carbon Flora," vol. i., p. 236 (*in part*).
Calymmatotheca, Zeiller, *Ann. d. Sci. Nat.*, 6e sér., Bot., vol. xvi., p. 182, 1883.
,, ,, "Flore foss. d. bas. houil. d. Valen.", p. 34, fig. 22, 1888.
,, Kidston, *Trans. Roy. Soc. Edin.*, vol. xxxiii., p. 137, 1887.
Sorocladus, Lesquereux, "Coal Flora," p. 327, 1880 (*in part*).

Description.—Fertile and barren pinnæ dissimilar; fertile pinnæ completely deprived of the limb; sporangia borne at the extremities of the ultimate ramifications of the secondary pinnæ, exannulate, large, oblong or linear, with thick walls whose cells are elongated in the direction of the longer axis, and united at their base round a common point of attachment. The synangia are composed of from 5-20 sporangia.

Remarks.—The sporangia appear to be attached around a small circular expansion of the extremity of the pedicel which bears them. They are quite free in their upper portion, but united to each other at their base. In *Calymmatotheca asteroides*, Lesqx., sp., there are usually six sporangia in a synangium, but in *C. bifida*, L. and H., sp., as many as twenty enter into its composition.

* Renault, *Ptychocarpus (Pecopteris) unita*, Brongt., sp. "Cours d. Botan. Foss.", 1883, p. 119, plate xx., figs. 11-19.

Dr. Stur has explained this fruit as consisting of so many segments of a split involucre, but, from the examination of many excellently preserved British specimens of the genus, there remains no doubt in my mind as to the sporangial nature of the component parts of this fructification, an explanation of their structure which was first given by Renault,* and later more fully illustrated by Zeiller.†

In Britain there are three species, which, from their fructification, are known to belong to *Calymmatotheca*:—*C. affinis*, L. & H., sp.; *C. bifida*, L. & H., sp.; and *C. asteroides*, Lesqx., sp. The fruit of the first was discovered by the late Mr. C. W. Peach in fine condition in the Midcalder Oil Shales, and described before the Bot. Soc. of Edin. as *Staphylopteris Peachii*, Ether. and Balf., being then considered a distinct plant, but it is now known to be the fruit of *Sphenopteris affinis*, L. & H.‡ The second species, *C. bifida*, has been found in fruit in the Lower Carboniferous of both Scotland and England, and has been described by myself; while the third, *C. asteroides*, has been collected in the Middle Coal Measures of England near Dudley by the late Mr. Henry Johnson. The affinities of *Calymmatotheca* are clearly Marattiaceous, and in their cup-like synangia they show some resemblance to the synangia of *Kaulfussia*, but in the latter the synangia are scattered on the back of the fronds whose limb is not in any way reduced or modified, and further in *Kalfussia* the sporangia are *united laterally* throughout their whole length.

In *Calymmatotheca*, on the other hand, the sporangia are borne on specially modified pinnæ, entirely deprived of their foliage, and are only united to each other at the base.

As far as my observation has gone, these fruiting pinnæ are only produced at the base of the frond.§

* Renault, *loc. cit.*, p. 198, plate xxxiii., figs. 17 and 18.

† *Loc. cit.*

‡ These specimens were subsequently figured and described by Mr. Peach—*Quar. Journ. Geol. Soc.*, vol. xxxiv., p. 131, plate viii.

§ See *Trans. Roy. Soc. Edin.*, vol. xxxiii., plate viii., fig. 1. (*C. bifida*, L. & H., sp.)

Crossotheca, Zeiller, 1883.

(Plate II., fig. 24.)

Crossotheca, Zeiller, *Ann. d. Sci. Nat.*, 6e sér., Bot., vol. xvi., p. 180.
,, ,, "Flore foss. d. bas. houil. d. Valen.", p. 33, fig. 21.
Sorotheca, Stur, "Zur Morph. und Syst. d. Culm u. Carbon Farne," p. 175.
,, ,, "Carbon Flora," vol. i., p. 273.
Sorocladus, Lesqx., "Coal Flora," vol. i., p. 327 (*in part*).

Description.—Fertile and barren pinnules dissimilar, the fertile pinnules having the limb much reduced or suppressed. Sporangia exannulate, tapering to a point at the apex, contiguous or more or less united among themselves, and suspended like a fringe from the margin of the fertile pinnule.

Remarks.—This genus has been fully described and figured by Zeiller from specimens from the coal-fields of the north of France.

The sporangia of *Crossotheca* are linear oblong, with the base slightly broader than the apex. Their walls are composed of cells elongated in the direction of the axis. According to Zeiller they appear to be united in pairs or perhaps in fours at the extremities of veins that are given off from a swelling of the pedicel, which terminates in a thickening in the centre of the fertile pinnule.

It is only lately that I have been able to include this genus in the British Palæozoic Flora. A few months ago I received from Mr. W. Hemingway, for examination, a small collection of Middle Coal Measure ferns from the neighbourhood of Barnsley, and among them I was pleased to find several examples of a small fern in fructification, which is evidently to be referred to *Crossotheca*.* This species differs from the other described members of the genus in several well-marked characters. It also offers an interesting example of how different in appearance the barren pinnules may be in the several members of the same genus.

In *Crossotheca Crepini*, for example, the barren pinnules are divided into several rounded lobes, whereas in the species from Yorkshire, which I previously named *Crossotheca fimbriata*, but have since found to be identical with Stur's *Calymmatotheca Schatzlarensis*, the barren pinnules are divided into narrow linear segments.†

* See *Annals and Mag. Nat. Hist.*, ser. 6, vol. ii., pp. 23 and 24, plate i., figs. 1-8.

† The true position of the plant is in *Crossotheca*.

I have just referred to Dr. Stur's interpretation of the structure of the fruit of *Calymmatotheca*, and here again he would apply the same explanation, but the views advocated by this author are altogether untenable by those who have had opportunity of examining well-preserved specimens of *Crossotheca*.

Renaultia, Zeiller, 1883 (Aug.).

(Plate II., fig. 25.)

Renaultia, Zeiller, *Ann. d. Sci. Nat.*, 6e sér., Bot., vol. xvi., p. 185, plate ix., figs. 16 and 17.

,, ,, "Flore foss. d. bas. houil. d. Valen.", p. 28, fig. 15, 1888.

Hapalopteris, Stur, "Zur Morph. und Syst. d. Culm u. Carbon Farne," p. 28 (issued Dec. 1883).

,, ,, "Carbon Flora," vol. i., p. 26, 1885.

Description.—Sporangia ovoid, either isolated or arranged in groups of from 2-5 at the extremity of the nerves towards the margin of the pinnule.

The walls of the sporangia are formed of cells elongated in the direction of the axis, but towards the apex the cells are more polygonal.

Remarks.—The foliage of the known species belonging to this genus is Sphenopteridian.

The hexagonal cells at the apex of the sporangia are very similar to those occurring at the apex of the sporangia of *Angiopteris*, but they are not differentiated to form an annulus.

The members of the genus hitherto discovered in Britain are *Renaultia (Sphenopteris) microcarpa*, Lesqx., sp. ("Coal Flora," p. 281, plate xlvii., fig. 2), the fruit of which was described by myself (*Ann. and Mag. Nat. Hist.*, ser. 5, vol. x., p. 9, plate i., figs. 9-14, 1882, and *Proc. Roy. Phys. Soc. Edin.*, vol. vii., p. 131, plate i., figs. 9-14 (excl. figs. 7 and 8 = *S. amœna*, Stur, sp.) from specimens discovered by Mr. James Bennie at Blairpoint, Dysart, Fife (Lower Coal Measures); and *Renaultia (Sphenopteris) gracilis*, Brongt., which was originally described by Brongniart from the mines near Newcastle-on-Tyne ("Hist. d. Végét. Foss.", p. 197, plate liv., fig. 2), of which the fruit has been observed by Renault ("Cours d. Botan. Foss.", 3e an., p. 190, plate xxxiii., figs. 1-4).

In the structure of the sporangia this genus has affinities with *Angiopteris*, but the arrangement of the fruit is very different.

Dactylotheca, Zeiller, 1883.

(Plate II., fig. 26.)

Dactylotheca, Zeiller, *Ann. d. Sci. Nat.*, vol. xvi., p. 184, plate ix., figs. 12-15.
,, ,, "Flore foss. d. bas. houil. d. Valen.", p. 30, fig. 16.
Sonftenbergia, Stur (*not* Corda), in "Culm Flora" (*in part*), "Carbon Flora," and "Morph. und Syst. d. Culm u. Carbon Farne."

Description.—Sporangia ovoid, exannulate; tapered to a point at the summit, and attached to the secondary veins a little distance above their origin. Cells of the sporangia wall elongated in the direction of the greater axis, among which is a longitudinal band of cells more elongated than the others, and in the direction of this line the sporangia open at maturity.

Remarks.—The fertile pinnules do not differ in form, or only very slightly, from the barren ones. The sporangia cover a considerable part of the under surface of the pinnules—and not only occupy their marginal portion, but lie lengthwise on the nerves, not placed to the right or left of them as in *Renaultia*, from the sporangia of which those of *Dactylotheca* further differ in being more elongated and having a band of more elongated cells.

The type of this genus is *Pecopteris dentata*, Brongt., which is frequent in the Upper and Middle Coal Measures of England.

The affinities of *Dactylotheca* also appear to be with *Angiopteris*.

Cyclotheca, Kidston, 1888.

(Plate II., fig. 27.)

Cyclotheca, Annals and Mag. Nat. Hist., July, 1888, p. 26, plate i., figs. 10-12.

Description.—Sporangia small, free, sessile, circular, exannulate, and arranged in two parallel rows.

Remarks.—This genus has been founded on a single specimen collected by Mr. P. Jack at Ellismuir, Baillieston, from shales above the Kiltongue Coal. (Lower Coal Measures.)

The fossil consists of several alternate linear pinnæ, each pinna being only represented by the two parallel rows of sporangia, between which probably lay the midrib.

In the structure of the individual sporangia they closely approach to those of *Myriotheca*, Zeiller, and *Renaultia*, Zeiller (*Ann. d. Sci. Nat.*, 6ᵉ sér., Bot., vol. xvi., pp. 185-186), but in *Myriotheca* the sporangia are oval and cover the *whole* of the

lower surface of the pinnule, and in *Renaultia* they are situated singly or in groups at the end of the veins. In *Cyclotheca*, on the other hand, the sporangia are circular and arranged in two long parallel rows. The specimen on which I have founded this genus has been named from these characters, *Cyclotheca biseriata*, Kidston.

Cyclotheca is Marattiaceous, but has not a very close relationship with any existing genus.

Myriotheca, Zeiller, 1883.

(Plate III., fig. 28.)

Myriotheca, Zeiller, *Ann. d. Sci. Nat.*, 6e sér., Bot., vol. xvi., p. 186, plate ix., figs. 18-20.
,, ,, "Flore foss. d. bas. houil. d. Valen.", p. 32, fig. 19.

Description.—Sporangia independent, exannulate, ovoid, sessile, covering the whole under surface of the pinnule; one sporangium placed beside the other without any apparent order.

Remarks.—The sporangia have a slightly elongated band of cells, at which part they seem to have opened for dehiscence. They appear to have been attached to the limb without any special receptacle.

The type of the genus *(M. Desaillyi)* belongs to the Sphenopterideæ, but the barren condition of the species is unknown, no barren pinnules having been found in union with the fruiting ones.

The genus, as learnt from the structure of the sporangia, is more closely related to *Angiopteris* than any other recent genus, but from this it differs much in the arrangement of its sporangia. It is, however, clearly Marattiaceous.

Myriotheca has not yet been observed in Britain.

Sphyropteris, Stur, 1883.

(Plate III., fig. 29.)

Sphyropteris, Stur, "Morph. und Syst. de Culm u. Carbon Farne," p. 23.
,, Stur, "Carbon Flora," vol. i., p. 16.
,, Zeiller, "Flore foss. d. bas. houil. d. Valen.", p. 31, fig. 17.
,, Kidston, *Trans. Roy. Soc. Edin.*, vol. xxxv., p. 402, plate i., fig. 3*a-d*.

Description.—Sporangia free, exannulate, sessile, placed on oblique elevated distant bands on a narrow membranous expan-

sion, which is situated at right angles to the midrib of the pinnæ or pinnules "like a hammer on its handle."

Remarks.—On a specimen of this genus (*S. obliqua*, Marrat, sp.) from the Middle Coal Measures, St. Helen's, near Liverpool, and now in the Liverpool Museum, the arrangement of the sporangia is clearly exhibited. The wall of the sporangium is composed of elongated cells which tend to a point at the apex. In some cases I have observed what seems to be a small terminal depression at the apex of the sporangium, and, though I cannot positively affirm that this depression is a terminal pore similar to what occurs in the fossil genus *Urnatopteris* and in the recent genus *Danæa*, still the appearance is so like that which occurs on some of my specimens of *Urnatopteris* that the idea is suggested that in *Sphyropteris* the dehiscence took place by a terminal pore. This point can only be determined by the discovery of better specimens. The sporangia show no trace of an annulus.

Among recent ferns there is none with which *Sphyropteris* can be compared in the curiously developed expansion on which the fruit is placed and in the arrangement of the sporangia, but should it be proved that dehiscence took place by a terminal pore, its affinities would be with *Danæa*.

I am indebted to the Curator and Trustees of the Liverpool Museum for kindly forwarding this and many other specimens to me for examination.

I have collected another member of this genus in fruit (*S. Boehnischi*, Stur) at Furnace Bank, Old Sauchie Tower, near Alloa. (Lower Coal Measures.)

All the species known to belong to *Sphyropteris* are Sphenopteroid in the character of their barren foliage.

Urnatopteris, Kidston, 1884.

(Plate III., fig. 30.)

Urnatopteris, Kidston, *Quar. Journ. Geol. Soc.*, vol. xl., p. 594.
,, Zeiller, "Flore foss. d. bas. houil. d. Valen.", p. 33, fig. 20.

Description.—Barren and fruiting fronds (or pinnæ) dissimilar; fruiting fronds (or pinnæ) deprived of the limb, and bearing along the secondary rachis of the pinnæ two parallel alternate rows of free, oval, exannulate sporangia which open by a small circular terminal pore for the dissemination of the spores.

Remarks.—The affinities of this interesting fructification are with the recent genus *Danæa*, in which, however, the fruit forms sessile synangia, which are immersed, linear, contiguous, occupying nearly the entire length of the venules and covering the whole under surface of the fertile fronds. In *Danæa* also the synangium consists of two rows of numerous laterally and oppositely connate sporangia, which united into a concrete mass form a linear synangium, each component sporangium of which opens by a circular terminal pore.

The fronds of *Danæa* attain from 1-3 feet in length, and are of firm texture; thus the recent genus in its general appearance forms a marked contrast to the delicate Sphenopteroid fern (*Sphenopteris tenella*, Brongt.) which is the type of the genus *Urnatopteris*.

The fruiting specimens of this fern, on which the genus was founded, were discovered some years ago in considerable plenty and in an excellent state of preservation, at Furnace Bank Colliery, Old Sauchie, near Alloa (Lower Coal Measures).

More recently Mr. Peter Jack has collected a good fruiting example at Scrawhill Colliery, near Airdrie. (Lower Coal Measures.)

Archæopteris, Dawson, 1882.

(Plate III., fig. 31 and fig. 32.)

Archæopteris, Dawson, "Plants of the Erian (Devonian) and Upper Silurian Formations of Canada," part 2, p. 98, 1882.
Palæopteris, Schimper (*not* Genitz), "Traité," vol. i., p. 475.
Cyclopteris, Forbes (*in part*), *Brit. Assoc. Report*, 1858, p. 75.

Description.—Frond very large, bipinnate, fruiting and barren pinnules dissimilar. *Barren* pinnules obovate, inequilateral, and contracted into a stalk-like slightly decurrent pedicel. Veins numerous, radiating from the base and dichotomising several times. The margin of the pinnule is generally more or less lacerated. *Fruiting* pinnules usually entirely deprived of the limb, and composed of a strong rachis-like vein on whose upper side are borne numerous oblong, blunt or pointed, sessile or shortly stalked, free, exannulate sporangia. The free barren extremity of the fruiting pinnules usually ends in several simple or divided thread-like filaments. The fertile pinnæ occupy the lower portion of the frond and usually bear one or two barren pinnules next the rachis, and a few at the apex of the

pinnæ are also frequently barren. On the main axis, between the pinnæ, are placed larger pinnules of the same general structure as those on the pinnæ. At the base of the rachis, which appears to be smooth, are two large stipules—one on each side (Plate III., fig. 32).

Remarks.—From several circumstances, this is one of the most interesting of palæozoic ferns. It was first described by Forbes in 1852 under the name of *Cyclopteris Hibernica* (*Brit. Assoc. Report*, 1852, p. 43), and since that time has passed under several generic names. *Archæopteris Hibernica* is one of the characteristic fossils of the yellow sandstones of the South of Ireland whose geological position is not clearly decided—some classifying them as Upper Old Red Sandstone, others with the Lower Carboniferous. Sufficient to us is the fact that in *A. Hibernica* is one of the oldest British palæozoic ferns, and of which there is almost complete information as to its fruit and external form.

The examination of this fern makes one very much inclined to say that there is nothing new under the sun, for there is combined in this plant all the essential characters of the recent Marattiaceæ.

While making a comparison between *A. Hibernica* and the recent Marattiaceæ, let us at once dismiss from our minds the difference in the form of the barren pinnules, as this is a matter of very secondary importance, and not of generic value.

First, as to the fruit. In *A. Hibernica* the sporangia are narrow, oval, sessile, or very short stalked, and usually pointed at both extremities, though occasionally they appear to be blunt. The structure of these sporangia approaches therefore more closely to those of *Danæa* and *Marattia* than to any other Marattiaceous existing genera, but in *Palæopteris* the sporangia are not identical with either of these, nor are they united to form a synangium.

Again, a most typical Marattiaceous character in *Archæopteris Hibernica* is the presence of the two large stipules at the base of the rachis. There are several fine specimens showing the stipules in the Collection of the Geological Survey of Ireland, and there is also another specimen which, from its peculiar condition of preservation, shows scattered distant vascular bundles like so many strands or threads running up the rachis. This specimen has probably suffered a slight decay of the more delicate cellular tissue before being fossilized, which has admitted of the vascular bundles being exposed as they are now seen. All the characters

just mentioned show that *A. Hibernica*, whose fronds attained a very large size, is clearly Marattiaceous and in its characters does not differ, as far as can be seen, in any of the essential marks from the recent members of that order.

The genus *Archæopteris* is widely distributed, occurring in Canada, the United States and Belgium, as well as in Ireland, and extending from the Devonian to the Coal Measures.

Unatheca, Kidston, *genus nov.*

(Plate III., fig. 33.)

Ptychocarpus, Kidston (*not* Weiss), *Trans. Roy. Soc. Edin.*, vol. xxxiii., p. 350.

Description.—Frond tripinnate (?); pinnæ sub-opposite, lanceolate; pinnules sub-opposite, oblong, usually bearing four pairs of oblong lobes and a terminal one. On each lobe is situated an oblong sporangium, placed horizontally, which opens by a longitudinal cleft.

Remarks.—The type of this genus was collected at Camerton, Somerset, from the "Radstock Series," of the Upper Coal Measures, and in my paper "On the Fossil Flora of the Radstock Series of the Somerset and Bristol coal-field," was provisionally placed in Weiss' genus *Ptychocarpus*. Subsequent investigation has shown that it must be removed from this genus, and the genus *Unatheca* is now proposed for it. It was originally described as *Ptychocarpus oblongus*, Kidston.*

Each pinnule bears an oblong sporangium placed horizontally and surrounded by the very narrow border of the limb of the pinnule. The sporangia (on the only specimen collected) show a longitudinal depression, presumably arising from a cleft, by means of which dehiscence has taken place. This cleft does not extend to the two ends, from which I have inferred that there is only one sporangium here, and not two lying in close proximity.

If my interpretation of this fructification be correct, the fern is Marattiaceous, but does not seem to have close affinity with any recent genus.

* *Op. cit.*, p. 350, plate xx., figs. 2, 2*a*.

C. GENERA OF UNCERTAIN AFFINITIES.

Zeilleria, Kidston, 1884.

(Plate III., fig. 34.)

Zeilleria, Kidston, *Quar. Journ. Geol. Soc.*, vol. xl., p. 590, plate xxv.
,, Zeiller, "Flore foss. d. bas. houil. d. Valen.", p. 57, fig. 37.
Calymmotheca, Stur (*in part*), "Zur Morph. und Syst. d. Culm u. Carbon Farne," p. 167.
,, Stur (*in part*), "Carbon Flora, vol. i., p. 236.

Description.—Involucres placed at the extremities of certain lobes of the pinnules, which are slightly produced to form a pedicel. In the earlier condition the involucres are globose and closed, but at maturity split into four valves. The structure and arrangement of sporangia are unknown.

Remarks.—Of this interesting fructification only the structure of the involucres is known; we are in ignorance as to the arrangement of the contained sporangia or spores. The species known to belong to this genus have all very delicate Hymenophyllaceous pinnules, but, in the absence of fuller knowledge of the fructification, their systematic position remains uncertain.

The genus is interesting, however, as proving the existence of an involucre among palæozoic ferns, which in its structure approaches very closely to that of the capsules of the Hepaticæ.

The type of the genus is *Sphenopteris delicatula*, Sternb., and the specimens on which the genus is founded originate from the Forest of Wyre, Worcestershire, and are preserved in the Collection of the British Museum.

Chorionopteris, Corda, 1845.

(Plate III., fig. 35.)

Chorionopteris, Corda, "Flora d. Vorwelt," p. 90, plate liv., figs. 10-15.
,, Zeiller, "Flore foss. d. bas. houil. d. Valen.", p. 58.

Description.—Sorus globular, terminal, composed of four ovoid sporangia enclosed in a thick-walled capsule formed by the prolongation of the nerve, at first entirely closed but subsequently opening into four valves.

Remarks.—This curious and anomalous fructification was ascribed to the Gleicheniaceæ by Corda and to the Cyatheaceæ by Schimper.* Zeiller, on the other hand, who enters fully into

* "Handb. d. Palæont.", vol. ii., p. 93.

the discussion of the affinities of this fossil, rejects the view that it has relationship with either of the genera mentioned above, and questions if it may not be Rhizocarpian.*

As far as I understand the plant there is little evidence for referring *Chorionopteris* to the Homosporous ferns. It may belong to that group, but if so there are no existing genera with which it can be compared, and it may with equal propriety be referred to the Heterosporous Filicaceæ as an aberrant form, though there does not appear to be sufficient known about the fossil to enable one satisfactorily to refer it to either group. As pointed out by Zeiller, the capsule, whose wall is composed of several layers of cells, appears to be formed from an extension of the vein and not to originate from the epidermal cells as in the Leptosporangiate ferns.

I include this very problematical genus here with the object of comparison with the genus *Zeilleria*. In this latter genus there is a true fern whose involucre splits into four valves. Beyond this, however, there are no data for a further comparison. The position of the fruit on the frond of *Zeilleria* also appears to be very different from that of *Chorionopteris*.

Neuropteris, Brongt., 1822.

(Plate III., fig. 36.)

Neuropteris, Brongniart, "Sur la Classification des Végétaux Fossiles," p. 33, 1822.

The only fruiting specimen of this large and common Coal Measure genus that has yet been described, is the imperfect example of *Neuropteris heterophylla*, Brongt., found by Mr. T. Stock in the Lower Coal Measure shales, Blairpoint, Dysart, Fife, and described by me sometime ago.†

The fossil shows an axis about 8 cm. long, which gives off apparently two pairs of lateral pinnæ. The terminal portion of the specimen ends in a number of dichotomous branchlets—the ultimate divisions being about 8 mm. long, and bearing the fruit at their summits. On the terminal part of the fossil there is no trace of the ordinary foliage pinnules. On the lower part of the specimen are shown what appears to be the remains of a pair of lateral pinnæ, each of which seems to have supported four

* Zeiller, *op. cit.*, p. 58.

† *Trans. Roy. Soc. Edin.*, vol. xxxiii., p. 150, plate viii., fig. 7.

fructifications. Associated with these pinnæ are the remains of a small number of ordinary barren pinnules. Of the two lower pinnæ, one is very incomplete, and only shows some fragments of the ordinary barren pinnules; the corresponding opposite pinna is, however, more perfect, and shows three fructifications and a portion of a pedicel of a fourth. At the base of this pinna are preserved some remains of the ordinary barren pinnules. It would appear, therefore, that each of the lateral pinnæ supported four fruits; and, on the terminal portion, though the remains of only eleven fructifications are seen, there were probably originally twelve. There may be combined in this part two lateral pinnæ and the apex of the frond, each bearing four fruits, but this cannot be clearly traced. On the same slab was another fragment of the fructification, but it is not shown in the figure here given.

In the description of this specimen I have refrained from employing the terms *indusium* or *sporangium* to the little expansions at the extremities of the pedicels, as I cannot determine their true structure, though they are apparently composed of two or four segments.

From the imperfect preservation of this fossil, it is quite impossible to form any conjecture as to the affinities of this genus; but Renault, from the examination of silicified specimens of the rachis of *Neuropteris*, has shown that they are Marattiaceous.*

Dicksoniites, Sterzel, 1881.

Dicksoniites, Sterzel, "Palæont. Char. d. ob. Steink. u. d. Rothlieg im erzgeb. Beck.", p. 74.
,, ,, *Botan. Centralbl.*, vol. xiii., no. 8/9, p. 317.
,, ,, *Zeitsch. d. deutsch. geol. Gesell.*, vol. xxxviii., p. 797.
,, Zeiller, "Flore Foss. d. bas. houil. d. Valen.", p. 62.

The fruit of *Pecopteris Pluckenetii*, Brongt., has been described by Sterzel, for which he has founded the genus *Dicksoniites*, but it is very imperfectly known. The fruit is situated at the extremities of the veins, and appears to consist of a raised circular collar in which were contained the sporangia, which were perhaps attached to a central receptacle. Probably this cup-shaped involucre was closed in the earlier stages of its development. In a fruiting specimen of this species which I received from Mr. E. Wilson, Clifton, collected at Welton, Somerset, and which shows the

* "Cours d. Botan. Foss.", 3e an., 1883, p. 169.

upper surface of the pinnules, the fructifications are seen to have been placed in little pockets which project like knobs on the upper surface of the pinnules.

Dicksoniites Pluckenetii, Brongt., sp., is not of unfrequent occurrence in the Upper Coal Measures at Radstock.*

SECTION III.

FERN STEMS.

Three genera of Tree Fern Stems occur in the British Coal Measures—

I. *Caulopteris*, Lindley and Hutton.
II. *Megaphyton*, Artis.
III. *Psaronius*, Cotta.

The first two genera are founded on external characters, derived from the form and arrangement of the frond scars, and the last on its internal organization.

I. Caulopteris, L. and H., 1832.

(Plate III., fig. 38.)

Caulopteris, Lindley and Hutton, "Fossil Flora," vol. i., p. 121.
Ptychopteris, Corda, "Flora d. Vorwelt," p. 76.
Stemmatopteris, Corda, "Flora d. Vorwelt," p. 76.
Sigillaria, Brongniart (*in part*), "Hist. d. Végét. Foss.", vol. i., p. 392.

Description.—Stems of arborescent ferns bearing distant or contiguous, circular or oval, smooth scars, arranged quincunc-ially, containing—

Type 1.—An inner circular or oval closed ring more or less following the contour of the frond scar; within this is a second oval scar, open at its upper aspect, the free ends being bent inwards, and forming the "horse-shoe" scar.

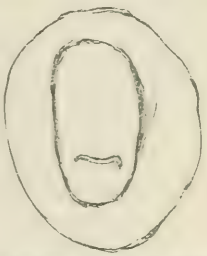
Type 2.—A closed inner circular or oval line, within which is a variously bent transverse scar. Stems of both types bearing numerous aërial rootlet cicatrices, placed on the stem between the frond scars.

Scars on stems deprived of their outer envelope, oval or elongate-elliptical, upper and lower extremities rounded or pointed, and generally confluent, occasionally showing within the scar traces of an inner oval cicatrice; whole stem striate.

Remarks.—Several explanations have been given of the struc-

* See *Trans. Roy. Soc. Edin.*, vol. xxxiii., p. 383.

ture of the frond scars of *Caulopteris*, some maintaining that the large inner circle of the frond is closed: others, that its superior margin is open, and that the two free ends bend inwards, and thus form the characteristic "horse-shoe" scar. Both of these descriptions of the structure of the scars appear to be correct. Zeiller was the first to demonstrate the closed nature of the inner circle of the scar of *Caulopteris*,* inside of which he detected a bent transverse band, which latter he regarded as the true vascular cicatrice. Grand 'Eury, however, states in his "Flore Carbonifère du Departement de la Loire, et du Centre de la France,"† that, though in the Upper Coal Measures of the Centre of France the *Caulopteris* with "horse-shoe shaped" inner scars are very rare, they do exist, and on such a specimen he founds his *Caulopteris protopteroides*, remarking at the same time that this form of *Caulopteris* was not so plentiful in France as he had seen it in England. Grand 'Eury was further able to show, from the examination of a silicious specimen of *Caulopteris*, that the inner closed circle, as well as the transverse central scar, is a vascular tract.



Caulopteris peltigera, Brongt., sp. Scar showing inner closed vascular tract, within which is contained the transverse cicatrice. (After Zeiller, half natural size.)

The genus has, as far as I am aware, only been found in England in the Upper Coal Measures, and represented by those species with the "horse-shoe" form of scar.

Another very interesting point has been brought out by Zeiller, in his paper to which reference has already been made, that those fossils for which Corda proposed the genus *Ptychopteris* (of which *Caulopteris macrodiscus* is the type) only represent the inner portion of *Caulopteris*, corresponding probably to the sheath of *sclerenchyma* which surrounds the peripheral portion of the stem. The figures Zeiller gives of *Caulopteris patria* ‡ and of *C. endorhiza*,

* "Note sur quelques troncs de Fougères fossiles." *Bull. Soc. Géol. d. France*, 3e sér., vol. iii., p. 574, 1874-5.

† Page 84.

‡ *Bull. Soc. Géol. d. France*, 3e sér., vol. iii., plate xvii., fig. 4. This is named on the plate *Caulopteris peltigera*, Brongt., sp. (?), but has since been described as a new species by Grand 'Eury under the name of *Caulopteris patria*. See also Zeiller, "Végét. foss. d. Terr. houil.", p. 100: and Grand 'Eury, "Flore Carbon. du départ. de la Loire," &c., p. 87.

Grand 'Eury,* show very beautifully the union of these two genera on the same specimen. On plate viii. of the work just mentioned is given an exceedingly fine example of a *Caulopteris* exhibiting the fronds attached to the stem.† This fine specimen confirms the accuracy of the position assigned to those fossils by Lindley and Hutton.

The internal structure of these stems is probably of the *Psaronius* type.

The genus *Caulopteris* is represented by a greater number of species on the Continent than in Britain. The only British species I have yet met with are—

Caulopteris primæva, L. and H.

Caulopteris primæva, Lindley and Hutton, "Fossil Flora," vol. i., plate xlii.

Loc. Radstock and Camerton, Somerset.

Hor. Upper Coal Measures.

Caulopteris anglica, Kidston.

Caulopteris anglica, Kidston, *Trans. Roy. Soc. Edin.*, vol. xxxiii., p. 392, plate xxvi., fig. 3.

Loc. Radstock and Camerton, Somerset.

Hor. Upper Coal Measures.

Caulopteris cyclostigma, Lesqx.

Caulopteris cyclostigma, Lesquereux, "Coal Flora of Pennsyl.", vol. i., p. 341.

Loc. Radstock and Camerton, Somerset.

Hor. Upper Coal Measures.

The *Ptychopteris* condition of these stems also occurs at the above localities, and has been included under the name of *Caulopteris macrodiscus*, Brongt., sp., in my paper on the Fossil Flora of the Radstock Area,‡ but it must not be regarded as a distinct species from the above, but only their decorticated condition, the specific identification of which it is often difficult to determine in this state.

* "Etudes sur le Terrain houiller de Comentry," vol. ii.; "Flore Fossile," by Renault and Zeiller, première partie, by R. Zeiller; *Bull. de la Soc. de l'Industrie minerale*, St. Etienne, 1888, plate xxxvi.

† *Loc. cit.*, *Pecopteris Sterzeli*, Zeiller.

‡ *Trans. Roy. Soc. Edin.*, vol. xxxiii.

II. Megaphyton, Artis, 1825.

(Plate III., fig. 39.)

Megaphyton, Artis, "Antedil. Phytology," p. 20.

Description.—Trunks bearing two opposite vertical rows of frond-scars; scars containing the vascular cicatrice, variously arranged and sometimes not well defined, but constant in its characters in the different species.

Remarks.—The only British specimens I have yet seen are English, and originate from the Middle and Upper Coal Measures. The genus requires a thorough revision as far as the British species are concerned. I therefore refrain from giving any list of the British representatives.

The type of *Megaphyton* is the *Megaphyton frondosum*, Artis,—from a Sandstone quarry, near Rowmarsh, Yorkshire—the counterpart of which is preserved in the British Museum.

III. Psaronius (Cotta *emend.*) Göppert, 1864.

(Plate III., fig. 40.)

Psaronius, Cotta, "Die Dendrolithen," p. 27, 1832.
,, Göppert, "Foss. Flora d. Perm. Form.", p. 46, 1864.
,, Schimper, "Traité d. Paléont. Végét.", vol. i., p. 716.
,, ,, in Zittel, "Handb. d. Palæont.", vol. ii., p. 148.
,, Corda, "Flora d. Vorwelt," p. 94.
,, Renault, "Cours d. Botan. Foss.", 3e an., p. 142, 1883.
,, Grand, 'Eury "Flore Carbon. du départ. de la Loire," &c., p. 92.

Description.—Stem generally thick, sometimes with a diameter of several feet. The principal mass of the stem formed of parenchymatous tissue, permeated with numerous adventitious rootlets, which arise from the usually numerous, central, bent and strap-shaped, concentrically arranged, vascular bundles. The vascular system, in relation to the bark is small, round or angular. Outer surface of trunk covered with numerous aërial rootlets.

Remarks.—The outer surface of the stems of *Psaronius* is clothed with a dense covering of aërial rootlets, similar to what is found on recent tree-fern stems—especially on their lower part. The vascular strands composing the vascular system, are of different form in the various species—being in transverse section sometimes single or double "horse-shoe" shape, their ends being often bent inwards—sometimes sinuous, strap-shaped or nearly straight.

The genus is more common in the Permian than in the Carboniferous formation.

Psaronius is very rare in Britain, and even the most perfect specimens found in this country are very fragmentary. These have been described by Professor Williamson as *Psaronius Renaultii.*

Psaronius is Marattiaceous, but differs from the recent Marattiaceous ferns in having a high erect stem. In the existing representatives the stem is but feebly developed. The large size of the vascular bundles, and their arrangement in *Psaronius* is also dissimilar, but the structural peculiarities of *Psaronius* would indicate its union with this group.

Psaronius Renaultii, Will.

Psaronius Renaultii, Will., *Phil. Trans.*, 1876, vol. clxvi., p. 10, plate iii., figs. 18, 20, 21 ; plate iv., figs. 19, 22*x*, 22, 22*xx*.
Psaronius, Will., ibid., part II., 1883, p. 464, plate xxx., fig. 16.

Remarks.—Only fragments of the stem of this species have been found, but the arrangement of the bundles appears to be similar to that which maintains in the other *Psaronii.* In a specimen discovered by Mr. G. Wild—the most perfect that has yet been found—the bundles are long and narrow, and bent into a flattened semicircle, their ultimate ends being further rolled inwards. This bundle has been surrounded by phloem sheath. In the ground tissue which surrounds the bundle are numerous resin or gum canals.

It is probable that *Psaronius* is a *Caulopteris* with its internal structure preserved.

Loc. From the Lancashire coal-field.

FERN PETIOLES.

Fern petioles showing their internal organization are of frequent occurrence at those localities in Britain where Carboniferous plants having their structure preserved are found, and many have been described by Dr. Williamson from Yorkshire and Lancashire as well as from Pettycur, Fifeshire.

The original workers founded a number of genera for the inclusion of such specimens, grounding the generic characters on the arrangement and form of the vascular bundles. Such a classification is, however, for scientific purposes entirely useless, for it is

found among recent ferns that the arrangement of the vascular bundles varies much in the same genus.

Certain recent genera contain species, the petioles of which, when examined in transverse section, show the vascular bundles to be arranged in very diverse manners. Conversely to this it is found that in genera which are quite distinct from each other, the arrangement of the vascular bundles is similar or identical. Therefore Dr. Williamson classifies together under the name of *Rachiopteris* all fern petioles which have sometimes been treated as belonging to distinct genera. From the present standpoint of our knowledge this is much the preferable course to take.

Time will not allow of our examining the various types of fern petiole structure in detail, but I have selected two—one representing the Annulate or Leptosporangiate ferns, the other the Exannulate or Eusporangiate ferns.

Structure of Existing Leptosporangiate Fern Petioles and Stems.

Let us now examine the structure of recent Leptosporangiate fern petioles or rhizomes, taking as our type *Pteris aquilina*, Linn.

The fundamental tissue of the fern stem is in great part composed of thin-walled parenchyma, but certain portions become differentiated from the rest, and their cells become firm and prosenchymatous *(sclerenchyma)* with much thickened walls of a brown colour. In transverse section this species shows two elongated narrow tracts of sclerenchyma situated on each side of the centre of the stem, between which are two of the three chief tracts of vascular tissue, and outside of one of the tracts of sclerenchyma is another principal vascular bundle; in addition there are a number of smaller vascular tracts or bundles forming an irregular circle outside those just described. The stem is surrounded by a thick layer of sclerenchyma which is thinned at two points where the fundamental tissue extends to the epidermal layer.

The xylem of the bundle rarely contains true vessels with perforated walls; it consists chiefly of long broad scalariform tracheids with occasionally bordered pits. True vessels do, however, occur in *P. aquilina* with the septa perforated in a scalariform manner.

At certain points between, but especially outside of, the scalari-

form tracheids, are found a few spiral and narrow tracheids. Within the bundle and mixed with the tracheids are frequently narrow thin-walled cells which contain starch.

The xylem is surrounded by phloem (bast) containing parenchymatous cells as well as sieve tubes. Between the phloem and the xylem is a layer of cellular tissue containing starch, and outside of the phloem (or bast) portion of the bundle is another layer of starch containing parenchymatous cells; and enclosing all is the bundle-sheath or *endodermis*. The last-mentioned layer is very distinct; the cells early become transformed into cork, and have usually a brownish colour.

The bundles in their course through the stem anastomise and form the so-called *netted cylinder*.

From the circumstances that the phloem surrounds the xylem on all sides, these bundles are called *concentric*.*

Excluding minor differences such is the typical structure of Leptosporangiate fern stems. In some, however, as in *Lastrea Filix-mas*, there is no sclerenchyma and in some other ferns the sclerenchyma is colourless.

In *Osmunda* the arrangement of the bundles differs somewhat from that which maintains in most of the other Leptosporangiate ferns, the bast portion of the bundle being only placed on that side of the xylem that faces outwards. Such bundles, from having the bast only on one side of the xylem are called *collateral*.

Structure of Fossil Leptosporangiate Petioles.

A considerable number of fern petioles belonging to this group have been described by various authors—but especially by Cotta, Corda, Renault, Grand 'Eury, and Williamson. Britain has perhaps produced a greater number of species than any other country, and these have been mostly fully and ably described by Professor Williamson in his Memoirs "On the Organisation of the Fossil Plants of the Coal Measures" which have appeared from time to time in the *Philosophical Transactions*. As these papers are very accessible, and should be studied by all students of fossil botany, only one or two of the many species that have been described are treated of here in detail, but references to other British species are given.

* Figures of transverse and longitudinal sections of *Pteris aquilina* are given in most handbooks on Structural Botany.

Rachiopteris, Williamson.

Vascular bundle H-shaped, or some modification of that form.

(Zygopteris, Corda.)

The fern petioles included in this group have the vascular bundle more or less prominently arranged in the form of an H, or what has been described as the "double-anchor" arrangement. In such species as *Rachiopteris Lacattii*, Renault, sp., or *R. di-upsilon*, Will., this is strongly marked. In *R. duplex*, though the form of the bundle is more hour-glass shaped, it must also be included in this section.

In the earlier part of this paper it was pointed out that the form of the bundle was quite insufficient for generic distinction, and no better proof of the truth of this statement could be found than the *Rachiopteris Grayii*,* Will., which was described in his last Memoir.†

Rachiopteris Lacattii, Renault.

(Plate IV., fig. 41.)

Rachiopteris Lacattii, Williamson, *Phil. Trans.*, vol. clxiv., 1874, p. 694, plate lvi., fig. 142; plate lvii., figs. 43-47; plate lviii., fig. 48; *ibid.*, vol. clxxx., 1889, p. 159; plate ii., fig. 6.

Zygopteris Lacattii, Renault, *Ann. d. Sci. Nat.*, 5e sér., Bot., vol. xii., p. 170, plate vii., fig. 12; plate viii., figs. 14-16; plate ix., fig. 13; "Cours. d. Botan. Foss.", 3e an., 1883, p. 101, plate xvi., fig. 1.

Description.—Petiole circular or oval, vascular bundle central, H-shaped in transverse section with the extremities of the two uprights generally bent inwards towards each other and forming the "double-anchor." The vascular bundle is surrounded by an "hour-glass shaped" tract of bast, which in turn is enclosed by the bundle-sheath. The space from the bundle-sheath to the periphery is occupied by cellular tissue, which, as it is traced outwards, gradually assumes the form of sclerenchyma, the sclerenchyma becoming specially characterised towards the periphery of the stem.

The tracheids of the cross-bar of the H-shaped vascular bundle are much larger than those of the arms, and are composed of *areolated* tracheids. In the two arms, the tracheids are very much smaller, especially in the outermost portion, from which the pinnæ bundles are given off. The larger tracheids in the arms are

* See next page. † *Phil. Trans.*, vol. clxxx., p. 155 *et seq.*, 1889.

areolated, and the smaller are scalariform. It is frequently very difficult to find a term which completely describes the nature of the wall-thickenings in the tracheids composing the vascular system, as so many modifications occur through which one form passes into the other.

Surrounding the vascular system, and within the soft bast, are the sieve tubes which form two irregularly curved lines, whose position probably varies a little in different examples. Enclosing the vascular system is the bundle-sheath. The cellular tissue outside of and surrounding the bundle-sheath is tabular in longitudinal section, but as it is traced outwards the cells become elongated and gradually transform themselves into a surrounding subcortical *sclerenchymatous* sheath.

Outside of the central bundle and in the ground tissue of the stem is usually one or more isolated tracts of vascular tissue. These are the vascular tracts that go off to the pinnæ.

Remarks.—In this petiole we see all the essential characters, though modified in detail, of those occurring in the rachis of *Pteris aquilina*, Linn., which has been already examined.

In regard to the "*Zygopteris*" form of fern structure, annulate sporangia have been found in connection with it by Renault, but even without this direct evidence, the internal structure of the stem, when compared with that of recent genera, would lead us to suspect that its fructification would consist of annulate sporangia.

Rachiopteris Grayii, Williamson.

Rachiopteris Grayii, Will., *Phil. Trans.*, vol. clxxx., 1889, p. 155, plate i., figs. 1-5 ; plate ii., fig. 5*a*.

Anachoropteris Decaisnii, Will. (*not* Renault), *Phil. Trans.*, vol. clxiv., 1874, p. 699, plate lviii., fig. 51.

Remarks.—This species is of special interest, as from it Professor Williamson has been able to show that the rhizomes which were placed by Renault in his genus *Anachoropteris*,* give rise to stems with the "double-anchor" form of vascular bundle *(Zygopteris)*. No two bundles could be more unlike in outer form than the typical bundle of *Zygopteris* and the five-rayed star-like bundle of *Anachoropteris*, but it has now been shown by Williamson that the latter gives birth to the former. In *Rachiopteris Grayii* there is a third form of bundle ; these are circular, and are probably those of the rootlets.

* Renault, *Ann. d. Sci. Nat.*, 5e sér., Bot., vol. xii., p. 161.

Rachiopteris bibractiensis, Renault, sp.

Rachiopteris bibractiensis, Will., *Phil. Trans.*, vol. clxiv., 1874, p. 697, plate lviii., figs. 49-50.

Zygopteris bibractiensis, Renault, *Ann. d. Sci. Nat.*, 5e sér., Bot., vol. xii., p. 171, plate ix., figs. 17-18.

Rachiopteris di-upsilon, Williamson.

Rachiopteris di-upsilon, Will., *Phil. Trans.*, part II., 1880, p. 537, plate xxi., figs. 90-91.

Rachiopteris duplex, Williamson.

Rachiopteris duplex, Will., *Phil. Trans.*, vol. clxiv., 1874, p. 687, plate liv., figs. 29-34, 36; plate lv., figs. 28, 35, 35*a*-35*b*, 35*c*, 35*f*, 37, 38, 40, 41; plate lvi., figs. 35*d*, 35*e*, 35*g*, 35*h*, 35*i*, 35*k*, 39, 41*a*.

,, *ibid.*, vol. clxxx., 1889, p. 159.

Arpexylon simplex, Will., *Phil. Trans.*, vol. clxiv., 1874, p. 690.

Rachiopteris insignis, Williamson.

Rachiopteris insignis, Will., *Phil. Trans.*, part II., 1880, p. 506, plate xvi., figs. 19, 20, 21, 22; plate xvii., fig. 23.

Vascular Bundle, Circular or Oval.

Rachiopteris corrugata, Williamson.

Rachiopteris corrugata, Will., *Phil. Trans.*, vol. clxvii., 1877, p. 213, plate v., figs. 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 19; plate vi., figs. 13, 14, 15, 16, 17, 18, 21, 22; plate vii., figs. 20, 23, 24.

,, *ibid.*, vol. clxxx., 1888, p. 158.

Rachiopteris cylindrica, Williamson.

Rachiopteris cylindrica, Will., *Phil. Trans.*, part II., 1878, p. 350, plate xxiv., figs. 80-85.

Rachiopteris robusta, Williamson.

Rachiopteris robusta, Will., *Phil. Trans.*, part II., 1880, p. 505, plate xvi., fig. 23*a*.

Rachiopteris hirsuta, Williamson.

Rachiopteris hirsuta, *Phil. Trans.*, vol. clxxx., 1889, p. 160, plate i., fig. 15; plate ii., fig. 11; plate iv., figs. 9, 10, 12, 13, 14.

Rachiopteris gleichenioides (?), Corda, sp.

Rachiopteris gleichenioides, Will., *Phil. Trans.*, part II., 1878, p. 350, plate xxiv., fig. 79.

Chorionopteris gleichenioides, Corda, "Flora d. Vorwelt," p. 90, plate liv., figs. 10-15.

Rachiopteris Oldhamia, Binney, sp.

Rachiopteris Oldhamia, Will., *Phil. Trans.*, vol. clxiv., 1874, p. 685, plate liii., figs. 20-24, 25*a*, 25*b*; plate liv., figs. 25, 26, 27.

Stauropteris Oldhamia, Binney, *Proc. Phil. Soc. Manchester*, vol. xi., p. 69.

Rachiopteris aspera, Williamson.

Rachiopteris aspera, Will., *Phil. Trans.*, vol. clxiv., 1874, p. 679, plate li., figs. 1-5; plate lii., figs. 6-13; plate liii., figs. 14-16.
,, *Phil. Trans.*, vol. clxxviii., 1887, p. 298.
Edroxylon, Will., *Proc. Roy. Soc.*, no. 136.

Description of fully developed rachis. Rachis oval, with superior surface flattened. Vascular system in transverse section "gutter-shaped" (consisting of a slightly convex transverse bar, from the ends of which spring two upright diverging bands). Periphery of rachis surrounded by a band of narrow-celled sclerenchymatous tissue arranged in wedges, separated from each other by narrow extensions of the parenchymatous tissue which occupies the area between the vascular bundle and the outer surface of the rachis. Outside of these wedges is an epidermis of two rows of cells. Situated within this parenchymatous tissue are numerous lenticular lacunæ, which, in the earlier condition of the plant, are filled with delicate parenchyma. The outer surface of the rachis bears numerous spine-like hairs, formed of several layers of small-celled parenchyma. Vascular bundle composed of reticulate, barred and spiral vessels; the two latter forms generally situated towards the periphery of the bundle. In the younger stems there are generally two oval vascular bundles directed obliquely towards each other. Foliage small, Sphenopteridian.

Remarks.—There is a probability that this rachis belongs to *Sphenopteris Höninghausi*, Brongt.,* and that the following species is the rhizome or stem of the same plant.

Dictyoxylon, Williamson.

Dictyoxylon, Williamson, *Monthly Microscopical Journ.*, Aug. 1869, p. 67.

Dictyoxylon Oldhamium, Binney, sp.

(Plate IV., figs. 42 and 43.)

Dictyoxylon Oldhamium, Will., *Monthly Micro. Journ.*, vol. ii., Aug. 1869, p. 66, plate xx., figs. 3-4.
,, *Brit. Assoc. Report*, 1871.
Dadoxylon Oldhamium, Binney, *Proc. Lit. and Phil. Soc. Manchester*, 1866.
Lyginodendron Oldhamium, Will., *Phil. Trans.*, 1873, p. 377, plate xxii., figs. 1-5; plate xxiii., figs. 6-9; plate xxiv., figs. 10-13, 15; plate xxv., figs. 14, 16, 17, 19, 20, 21; plate xxvi., figs. 18, 22-25.

* "Hist. d. Végét. Foss.", p. 199, plate lii. Andræ, "Vorwelt Pflanzen," p. 13, plates iv.-v.

Lygindendron Oldhamium, Will., "On some Anomalous Oolitic and Palæozoic Forms of Vegetation," *Proc. Roy. Inst. of Great Britain*, vol. x., 1883, p. 7, fig. 7.

Description.—In small stems (or rhizomes?) the pith is at first very small or scarcely discernible, and is surrounded by a ligneous zone—the primary vascular system. As the stem (or rhizome?) increases in size, it is accompanied by a considerable increase in the dimensions of the pith, which is composed of polygonal cells, arranged somewhat in vertical rows. With the increase of the pith in volume, the primary vascular bundle becomes split into segments, which are carried outwards by the increasing pith, and eventually they appear as so many isolated vascular tracts irregularly placed around the periphery of the pith. The largest vessels of the primary bundle are those surrounding the pith.

Outside of the primary vascular bundle is developed a cambium layer, from which the secondary ligneous zone is formed. This zone forms a complete circle, the vessels next to the cambium being smaller than those more distant. This bundle is divided into wedges—sometimes very narrow—by numerous prominent medullary rays, frequently of several layers in thickness. This zone contains a greater proportion of medullary rays than of ligneous tissue. The vessels are reticulated.

The bark consists of three zones:—an inner parenchymatous zone, a middle sclerenchymatous zone, and an outer parenchymatous zone. The inner parenchymatous zone consists of delicate cells, and is characterised by the presence of denser-walled, irregular star-shaped patches of cellular tissue. Within this zone and close to the secondary vascular circle are three to five, but generally four, separate vascular tracts. They are usually each composed of two bundles, slightly separated, but may be formed of only one bundle. These isolated vascular tracts also increase by exogenous growth. The component vessels are chiefly reticulated, but along with these are smaller ones of the barred type. The second zone of the bark consists of narrow wedges of sclerenchyma, much elongated and thickened by internal deposits of lignine. These are separated from each other by narrow tracts of the parenchymatous tissue. The sclerenchymatous bands in their vertical course anastomise and form a netted cylinder. The last and outermost zone of the bark consists of parenchymatous tissue. No true epidermal layer has yet been observed.

The outer surface of the stem is ornamented with fusiform or lozenge-shaped elevations. (Plate IV., fig. 43.)

Remarks.—The isolated bundles in the inner zone of the bark are supposed to originate in the same, and it seems most probable that they are the bundles which go off to the leaf-organs.

Dr. Williamson, from the fusiform elevations on the outer surface of the bark, as figured by him,* identified his genus *Dictyoxylon* with Gourlie's genus *Lyginodendron.*† I have examined Gourlie's type, and feel satisfied that it is only a fragment of an old *Lepidodendron* in a similar condition to that figured by Dawson ‡ and those described by myself in the *Ann. and Mag. Nat. Hist.*§ from which I believe Williamson's *Lyginodendron* to be very distinct. Also Corda's figure of *Sagenaria fusiformis*‖ which Williamson regards as generically identical, must be excluded, as it is a true *Lepidodendron.*

Although treating *Dictyoxylon Oldhamium* as a distinct species, there appears to be very little room for doubting that it is the stem or rhizome which produced the petioles described under the name of *Rachiopteris asper*,¶ about which there is no doubt as to their belonging to a true fern, as the pinnules have been found attached to them. I give here, for comparison with the outer surface of *Lyginodendron Oldhamium*, a figure of a portion of a large rachis of *Sphenopteris Höninghausi* (Plate IV., fig. 44), the outer surface of which is divided into fusiform or rhomboidal areas, in the centre of which is a little dot, from which the spiny thorn-like scale has fallen.**

Those interested in this subject must consult Dr. Williamson's Memoir†† in which the structure of *Lyginodendron* is most fully and ably described.

* *Loc. cit.*, plate xxvii., 1873.

† *Proc. Phil. Soc. of Glasgow*, vol. i., p. 108, 1841-44.

‡ "Acadian Geol.," 2nd ed., 1868, p. 455, fig. 170*c*.

§ Vol. xvi., page 166-7, 1885. ‖ "Flora d. Vorwelt," plate vi., fig. 4.

¶ This view is also held by Williamson (*Phil. Trans.*, vol. clxxviii., 1887, p. 298), and Count de Solms.

** Since this paper was read, Professor Williamson announced at the meeting of the British Association, Newcastle, 1889, that he had now absolute evidence that the small fern petioles, named *Rachiopteris asper*, were the branches of *Dictyoxylon Oldhamium.* This announcement carries with it the more important discovery, that in the stem of a Carboniferous fern we have undoubted evidence of the presence of a *cambium layer.*

†† *Loc. cit.* iv., 1873.

Dictyoxylon (?) *anomalum*, Williamson, sp.

Lyginodendron (?) *anomalum*, Will., *Phil. Trans.*, part II., 1878, p. 352, plate xxv., figs. 90, 91, 92.

HETERANGIUM, Corda.

Corda, "Beitr. z. Flora d. Vorwelt," p. 22, 1867.

Heterangium Grievii, Williamson, sp.

Dictyoxylon Grievii, Will., *Brit. Assoc. Report.*, 1871.

Heterangium Grievii, Will., *Phil. Trans.*, 1873, p. 394, plate xxviii., figs. 30, 31, 34, 46; plate xxix., figs. 32, 33, 35; plate xxx., figs. 36-44; plate xxxi., figs. 45, 47, 49.

,, Will., *Phil. Trans.*, 1872, p. 283.

,, Will., *ibid.*, vol. clxxviii., 1887, p. 298.

Remarks.—This is a most interesting species, but as *Dictyoxylon Oldhamium* has been described so fully, the student must refer to Professor Williamson's Memoir for a description of this plant. I would only point out that one of the characteristic points in the structure of this species—the dark transverse bars of thickened tissue in the cortex—occur in *Sphenopteris elegans*, Brongt., and in *S. grandifrons*, Sauveur. Of the former, fine specimens showing this character have been figured by Stur.* I have no doubt as to *Heterangium Grievii* being a fern rachis.

Heterangium Tiliæoides, Williamson.

Heterangium Tiliæoides, Will., *Phil. Trans.*, vol. clxxviii., 1887, p. 289, plate xxi., figs. 1, 3, 4, 6, 10, 16, 19; plate xxii., figs. 2, 5, 7, 8, 11, 13, 14, 15, 17, 18; plate xxiii., figs. 9, 12.

KALOXYLON, Williamson.

Phil. Trans., vol. clxvi., 1876, p. 23.

Kaloxylon Hookeri, Williamson.

Kaloxylon Hookeri, Will., *Phil. Trans.*, vol. clxvi., 1876, p. 13, plate iv., fig. 29; plate v., figs. 23-27; plate vi., figs. 28, 30-33; plate vii., figs. 34-38.

,, Will., *ibid.*, vol. clxxviii., 1887, p. 293, plate xxiii., figs. 20, 21, 24, 25, 26, 29, 29*a*; plate xxiv., figs. 22, 27, 28, 30, 31, 32, 33, 33*a*, 34, 34*a*, 35, 35*a*, 36, 36*a*, 37, 37*a*.

Remarks.—The position of this fossil is not satisfactorily determined, but it is probably a type of fern structure.

* "Culm Flora," plate xxx., fig. 5; plate xxxi., fig. 4.

Structure of the Stem of Existing Marattiaceæ.

For this group *Marattia laxa*, Kunze, may serve as our type.

The fundamental tissue consists of thin-walled parenchyma, in which the separate vascular bundles are arranged in two or more circles, the inner circles being somewhat irregular.

A sclerenchymatous tissue forms a complete sub-epidermal circle, but at certain parts of its course much larger cells of sclerenchymatous tissue form radial tracts in the band. This layer is separated from the epidermis by a band of cellular tissue of 8-10 cells in thickness. Scattered throughout the stem, both in the sclerenchymatous and fundamental tissue, are numerous gum canals.

The xylem consists of scalariform tracheids surrounded on all sides by phloem, in which the small sieve tubes are placed.

There is no endodermis (bundle-sheath), the absence of which character forms an important point of distinction between the Marattiaceous and the Leptosporangiate fern stem structure.

Structure of the Stem of Fossil Marattiaceæ.

As a typical fossil Marattiaceous fern stem *Myelopteris* may be taken.

Myelopteris, Renault.

Myelopteris, Renault, "*Etude du genre Myelopteris*," Mem. Acad. d. Sciences, vol. xxii., no. 10, 1875, plates i.-v.

,, "Cours. d. Botan. Foss.", 3e an., 1883, pp. 35 and 165, plate xxviii., figs. 2, 3.

,, Williamson, *Phil. Trans.*, vol. clxvi., p. 1, plate i., figs. 1, 2, 3, 4, 4*, 10, 12; plate ii., figs. 5, 6, 7, 7*, 8, 11, 16; plate iii., figs. 9, 13, 14, 15; plate iv., fig. 17.

The fundamental tissue is parenchymatous, in which are placed the vascular bundles. The outermost are placed in a circle, but those within this outermost circle are not so regularly placed.

The stem is surrounded by a sclerenchymatous sheath, which is separated from the epidermis by a layer of parenchyma of several cells in thickness. The sclerenchymatous band is formed of wedge-shaped portions, whose apices are directed towards the centre of the stem—their broader and outer ends being united among themselves to form a solid band. Immediately within this sclerenchymatous zone there are occasionally isolated scleren-

chymatous tracts arranged concentrically. Scattered throughout the stem and sclerenchymatous zone are numerous gum canals.

The bundles are composed of a xylem portion (Plate IV., fig. 45*a*) formed of spiral vessels, and usually directed towards the centre of the stem and a phloem portion directed outwards. (Plate IV., fig. 45*b*.) All bundles do not, however, hold the same position in regard to the axis of the stem, but some are often placed obliquely to it. The phloem portion is rarely preserved, but its place is indicated by a large opening.

There is therefore in the bundles of *Myelopteris* (Plate IV., fig. 45), an arrangement similar to that which occurs in *Ophioglossum vulgatum* (Plate IV., fig. 46) and *Osmunda*, where the bundles are collateral.

The arrangement of the bundles, which are devoid of a bundle-sheath (though the cells of the ground tissue that immediately surround them are slightly smaller in size than those forming the other portions of the ground mass), and the presence of numerous true gum canals, show the Marattiaceous nature of the petioles under examination.

Some of these Myelopteroid stems with structure preserved fortunately had their pinnules attached, from which Renault was enabled to determine that they belong in part to *Alethopteris* and *Neuropteris*.

Conclusion.

Though the botanist who has hitherto confined his investigations to the study of recent ferns, might think the occurrence of a *cambium* or *meristem* layer and *medullary rays* in the stems of ferns an impossibility, still this is not so. In the fossil lycopods, the increase of the secondary vascular system by exogenous growth, is a constant character, and it was by this means they were enabled to attain to arborescent dimensions. The presence of a *cambium* among recent lycopods is still found in the genus *Isoetes*. In examining the fructification and structure of Carboniferous ferns, the comprehensive type of palæozoic fern structure cannot fail to impress itself on the observer. The structures there found in union, appear to have subsequently split up and gone in different lines.

Writing in regard to this subject Professor Williamson says, "... one thing is certain, viz., that in their internal

organization they present combinations of tissues that find no representatives amongst living plants. Possibly they are the generalized ancestors of both ferns and cycads, which transmitted their external contours to the former and their exogenous modes of growth to the latter types. In considering this possibility we must not forget that in *Stangeria** we have a still living plant in which the stem of a cycad bears fronds, the leaflets of which retain the dichotomous nervation of a true fern. The *Stangeria* has retained, not only the primative exogenous stem of some ancestral type, in common with its other cycadean relatives, but also the peculiar fern-like leaflets, which may also have come down to it from palæozoic times. Hence we have here a combination of fern-like features and an exogenous mode of growth. Such being the case, it need not startle us if we have to conclude that a similar combination existed during the Carboniferous age."†

Before concluding this Memoir, I would wish to acknowledge the assistance which has been willingly afforded me in all cases by many brother botanists and geologists. In particular cases their names have been already mentioned, but to many my indebtedness is of such a nature that it cannot be individually stated, though none the less valuable, and to these I would now tender my sincere thanks. I cannot, however, omit mentioning the names of Professor Williamson; Mr. W. Cash, Halifax; and Mr. G. Wild, Brardsley.

Literature specially referring to the Fructification and Internal Structure of Carboniferous Ferns.

Artis, E. T.—Antediluvian Phytology. (Plates.) London, 1825.

Baily, W. H.—On the Fructification of *Cyclopteris Hibernica*, Forbes, from the Upper Devonian or Lower Carboniferous Strata at Kiltorkan Hill, county of Kilkenny. *Brit. Assoc. Report*, 1858, part II., pp. 75-76.

,, On *Corynepteris*, a new generic form of fossil fern, with observations on the associated plants from the Coal Measures of Glin, county of Limerick. *Nat. Hist. Review*, vol. vii., p. 258. (Plate.) 1860.

Brongniart, A.—Histoire des végétaux fossiles, vol. i. (Plates.) 1828-37.

* I have been informed that the specimens of *Stangeria* which were first examined consisted only of fronds and were described as a fern. On the subsequent arrival of the fruit of the species it was found to be a cycad.

† *Phil. Trans.*, vol. clxxviii., 1887, p. 298.

Brongniart, A.—Tableau des genres de végétaux fossiles considérés sous le point de vue de leur classification botanique et de leur distribution geologique. Dictionnaire universel d'histoire naturelle, vol. xiii., p. 52. 1849.

Bureau, E.—Sur la fructification du genre *Callipteris*. *Comptes Rendus*. (Plate.) 22nd June, 1885.

Carruthers, W.—Notes on some Fossil Plants. *Geol. Mag.*, vol. ix. (Plate.) 1872.

,, On the Tree Ferns of the Coal Measures and their affinities with existing forms. *Brit. Assoc. Report*, p. 98. 1872.

,, On the Tree Ferns of the Coal Measures and their relations to other living and fossil forms. *Quar. Journ. Geol. Soc.*, vol. xxix., p. 380. 1873.

Corda, A. C.—Beiträge zur Flora der Vorwelt. (Plates.) Prag. 1845.

Cotta, B.—Die Dendrolithen, in Beziehung auf ihren inneren Bau. Dresden and Leipzig. 1832.

Crépin, F.—Description de quelques plantes fossiles l'étage des Psammites du Condrez. (Dévonien supérieur.) *Bull. l'Acad. Roy. de Belgique*, 2e sér., vol. xxxviii. (Plates.) 1874.

Dawson, Sir W.—The Fossil Plants of the Devonian and Upper Silurian Formations of Canada. (Plates.) Part I., Montreal, 1871; part II., 1882.

,, On New Tree Ferns and other Fossils from the Devonian. *Quar. Journ. Geol. Soc.*, vol. xxvii., p. 269. (Plate.) 1871.

,, Notes on New Erian (Devonian) Plants, *ibid.*, vol. xxxvii., p. 299. (Two plates.)

Feistmantel, O.—Die Versteinerungen der Böhmischen Kohlenablagerungen. *Palæontographica*, vol. xxiii. (Plates.) 1874-5.

Feistmantel, K.—Der Hangendflötzzug im Schlau-Rakonitzer Steinkohlen-Becken. *Archiv. für Naturwissensch. Landesdurchforschung v. Böhmen*, vol. iv., no. 6, Geol. Abth. (Plates.) Prag. 1881.

Felix, J.—Untersuchungen über den inneren Bau Westfälischen Carbon Pflanzen. *Abhand. d. K. geol. Landes-Anstalt*, vol. vii., heft 3. (Plates.) Berlin, 1886.

Fontaine, W. M. and J. C. White.—The Permian or Upper Carboniferous Flora of West Virginia and S.W. Pennsylvania. (Plates.) Harrisburg, 1880.

Geinitz, H. B.—Die Versteinerungen der Steinkohlen-formation in Sachsen. (Plates.) Leipzig, 1855.

Germar, E. F.—Die Versteinerungen des Steinkohlengebirges von Wettin und Löbejun (im Saalkreise, &c.) (Plates.) Halle, 1844-53.

Göppert, H. R.—Die fossilen Farrnkraüter. Systema filicum fossilium. (Plates.) Breslau, 1836.

,, Die Gattungen der fossilen Pflanzen. (Plates.) Bonn, 1841.

,, Die fossile Flora der Permischen Formation. *Palæontographica*, vol. xii. (Plates.) 1864-5.

Grand 'Eury, C.—Flore Carbonifère du Département de la Loire, et du Centre de la France. (Plates.) Paris, 1877.

Gutbier, A. von.—Uber einen fossilen Farrnstamm, *Caulopteris Freisleben*i, aus dem Zwickauer Schwarz kohlengebirge. (Plates.) Zwickau, 1842.

,, Die Versteinerungen des Rothliegenden in Sachsen. (Plates.) Dresden and Leipzig, 1849. (In die Versteinerungen des Zechsteingebirges und Rothliegend oder des Permischen Systems in Sachsen, by Geinitz and Gutbier.)

Kidston, R.—On the Fructification of *Eusphenopteris tenella*, Brongt., and *Sphenopteris microcarpa*, Lesqx. *Annals and Mag. Nat. Hist.*, vol. x., 1882; and *Proc. Roy. Phys. Soc. Edin.*, vol. vii., p. 129. (Plate.) 1882.

,, Report on the Fossil Plants collected by the Geological Survey of Scotland in Eskdale and Liddesdale. *Trans. Roy. Soc. Edin.*, vol. xxx., p. 531. (Plates.) 1883.

,, On the Fructification of *Zeilleria* (*Sphenopteris*) *delicatula*, Sternb., sp.; with remarks on *Urnatopteris* (*Sphenopteris*) *tenella*, Brongt., and *Hymenophyllites* (*Sphenopteris*) *quadridactylites*, Gutbier, sp. *Quar. Journ. Geol. Soc.*, vol. xl., p. 590. (Plate.) 1884.

,, Notes on some Fossil Plants collected by Mr. R. Dunlop, Airdrie, from the Lanarkshire Coal-field. *Trans. Geol. Soc. Glas.*, vol. viii., p. 47. (Plate.) 1886.

,, On the Fructification of some Ferns from the Carboniferous Formation. *Trans. Roy. Soc. Edin.*, vol. xxxiii., p. 137. (Plates.) 1887.

,, On the Fossil Flora of the Radstock Series of the Somerset and Bristol Coal-field. (Upper Coal Measures.) *Trans. Roy. Soc. Edin.*, vol. xxxiii., p. 335. (Plates.) 1888.

,, On the Fructification and Affinities of *Archæopteris Hibernica*, Forbes, sp. *Annals and Mag. Nat. Hist.*, p. 412. June, 1888.

,, On the Fructification of two Coal Measure Ferns. *Annals and Mag. Nat. Hist.*, p. 22. (Plate.) July, 1888.

Lesquereux, L.—Descriptions of Fossil Plants in Geol. Survey of Illinois, vol. ii., 1866, and Palæontology, vol. iv. (Plates.) Chicago, 1870.

,, Atlas of the Coal Flora of Pennsylvania and of Carboniferous Formation throughout the United States. Harrisburg, 1879. Text, vols. i.-ii., 1880; vol. iii. 1884.

Peach, C. W.—On the Circinate Vernation, Fructification, and Varieties, of *Sphenopteris affinis* and on *Staphylopteris* (?) *Peachii* of Etheridge and Balfour, a genus of plants new to British Rocks. *Quar. Journ. Geol. Soc.*, vol. xxxiv., p. 131. (Plate.) 1877.

Renault, B.—Etude du quelques végétaux silicifiés des environs d'Autun. I. Etude sur le Tige des *Zygopteris*. II. Etude sur le Tige des *Anachoropteris*. *Ann. d. Sci. Nat.*, 5e sér., Botanique, vol. xii., p. 161. (Plates.) Paris, 1869.

,, Recherches sur les végétaux silicifiés d'Autun. Etude du genre *Myelopteris*, no. 10. *Mem. Acad. d. Sci. du l'Institute National d. France*, vol. xxii. (Plates.) Paris, 1875.

,, Cours de Botanique Fossile. Troisième année. Fougères. (Plates.) Paris, 1883.

Renault, B. and *Zeiller, R.*—Sur les troncs Fougères du Terrain houiller supérieur. *Comptes Rendus.* January, 1886.

Schenk, A.—Die fossilen Pflanzenreste, Breslau, 1888. (From Handb. d. Botanik, vol. iv.)

Schimper, W. P.—Traité de Paléontologie végétale. 3 vols., with atlas. Paris, 1869-74.

,, *in* Zittel's Handbuch der Palæontologie. II. band, lief. i. (Woodcuts.) München, 1879.

Stenzel, K. G.—Uber die Starrsteine. *Verhandl. d. K. Leop. Carol. Akad. d. Naturforscher.*, vol. xxiv., p. 751. (Plates.) 1854.

Sterzel, T.—Uber *Dicksoniites Pluckenetii;* Schloth., sp. *Botanisches Centralblatt*, vol. xiii., nos. 8/9. (Plate.) 1883.

,, Uber den grossen *Psaronius* in der Naturwissenschaftlich Sammlung der Stadt Chemnitz. X. *Bericht de Naturw. Gesell. zu Chemnitz.* 1884-86. (Plates.) 1887.

Strasburger, E.—Uber *Scolecopteris elegans*, Zenk., Einen fossilen Farn aus der Gruppe der Marattiaceen. *Jenaische Zeitschrift*, vol. viii., p. 81. (Plates.) 1874.

Stur, D.—Die Culm Flora, vols. i.-ii. *Abhandl. d. K. K. geol. Reichsanstalt*, vol. viii. (Plates.) Vienna, 1875-77.

,, Zur Morphologie und Systematik der Culm und Carbonfarne. *Sitzb. der K. Akad. der Wissensch.*, vol. lxxxviii., p. 633. 1883.

,, Die Carbon Flora der Schatzlarer Schichten. Abth. 1. *Abhandb. d. K. K. geol. Reichsanstalt*, vol. xi. (Plates.) Vienna, 1885.

Weiss, C. E.—Fossile Flora der jüngsten Steinkohlen-formation und des Rothliegenden im Saar-Rhein-Gebiete. (Plates.) Bonn, 1869-72.

Williamson, W. C.—On the Structure and Affinities of some Exogenous Stems from the Coal Measures. *Monthly Micro. Journ.*, vol. ii., p. 66. 1869.

,, On some Anomalous Oolitic and Palæozoic Forms of Vegetation. *Proc. Roy. Inst. of Great Britain*, vol. x., 1883.

,, Memoirs on the Organization of the Fossil Plants of the Coal Measures. *Phil. Trans.* (Plates.) London. IV. *Dictyoxylon, Lyginodendron*, and *Heterangium.* 1873. VI. Ferns. 1875. VII. *Myelopteris, Psaronius*, and *Kaloxylon.* 1876. VIII. Ferns, &c. 1877. IX. Ferns, &c. 1878. X. Ferns, &c. 1880. XII. *Psaronius*, &c. 1883. XIII. *Heterangium* and *Kaloxylon.* 1887. XV. Ferns, &c. 1889.

Zeiller, R.—Végétaux fossiles du Terrain houiller de la France. (Extrait du tome iv. de l'explication de la carte géologique de la France.) (Plates.) Paris, 1880.

,, Notes sur la Flore houillère des Asturies. *Mem. de la Soc. Géol. du Nord.* Lille, 1882.

,, Fructifications de Fougères du Terrain houiller. *Ann. d. Sci. Nat.*, 6e sér., Botanique, vol. xiii., p. 217. (Plates.) 1882.

,, Sur quelques genres de Fougères fossiles nouvellement crées. *Ann. d. Sci. Nat.*, Botanique, vol. xvii. 1844.

,, Sur la dénomination de quelques nouveau genres de fougères fossiles. *Bull. de la Soc. Géol. de France*, 3e sér., vol. xii., p. 366. 1884.

,, Etudes des Gites Mineraux de la France. Bassin houiller de Valenciennes. Description de la Flore fossile. Atlas of 94 plates. Paris, 1886. Text, 1888.

Zenker, H. C.—*Scolecopteris elegans*, Zenk. Ein neues fossiles Farrngewächs mit Fructificationen. *Linnæa*, vol. xi., p. 509. (Plate.) Halle, 1837.

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Note.—The woodcuts, fig. 1 and fig. 2, have been kindly lent by the Council of the Royal Society of Edinburgh, to whom my thanks are due.

EXPLANATIONS TO PLATES.

Plate I.

Fig. 1.—Sporangium of *Hymenophyllum Tunbridgense*, Sm. (enlarged). *a.* Annulus.

,, 2.—Sporangium of *Alsophila excelsa*, Br. (enlarged). *a.* Annulus.

,, 3.—Sporangium of *Polypodium vulgare*, Linn. (enlarged). *a.* Annulus.

,, 4.—Sporangium of *Todea Africana*, Willd. (enlarged). *a.* Annulus.

,, 5.—Sporangium of *Mertensia gigantea*, Presl. (enlarged). *a.* Annulus.

,, 6.—Sporangium of *Anemidictyon Phyllitidis*, J. Sm. (enlarged). *a.* Annulus.

,, 7.—*Marattia alata*, Sm. Synangium (seen from above and in section, slightly enlarged).

,, 8.—*Angiopteris erecta*, Hoffm. Synangium (seen from above and in section, enlarged).

,, 9.—*Danæa alata*, Sm. Synangium (seen obliquely and in section, enlarged).

,, 10.—*Kaulfussia Assamica*, Griff. Synangium (showing upper and lower aspect, enlarged). Figs. 1-5 and 7-10, after Hooker; fig. 6, after Luerssen.

,, 11.—*Annulate sporangium*, showing echinate spores. From the Coal Measures, Dulesgate (enlarged). (From a photomicrograph.)

,, 12.—*Annulate sporangium*, showing sub-triangular spores. From the Coal Measures, Halifax (enlarged). (From a photomicrograph.)

,, 13.—*Annulate sporangium*. From the Coal Measures, Halifax (enlarged). (From a photomicrograph of a specimen lent by Mr. W. Cash.)

,, 14.—*Hymenophyllites quadridactylites*, Gutbier, sp. Fruiting pinnule and sporangia (enlarged). After Zeiller.

,, 15.—*Oligocarpia Brongniarti*, Stur. *a.* Fruiting pinnules; *b.* and *c.* groups of sporangia; *d.* sporangium (all enlarged). After Zeiller.

,, 16.—*Senftenbergia elegans*, Corda. *a.* Fruiting pinnule; *b.* sporangium (both enlarged). After Corda.

,, 17.—*Corynepteris coralloides*, Gutbier, sp. *a.* and *b.* Portions of fruiting pinnules (enlarged); *c.* group of sporangia (more highly enlarged). After Zeiller.

,, 18.—*Zygopteris pinnata*, Grand 'Eury. Group of sporangia (enlarged); *b.* section of sporangium. After Zeiller.

,, 19.—*Schizostachys sphenopteroides*, Kidston. *a.* Two pinnules (natural size); *b.* sporangia (enlarged).

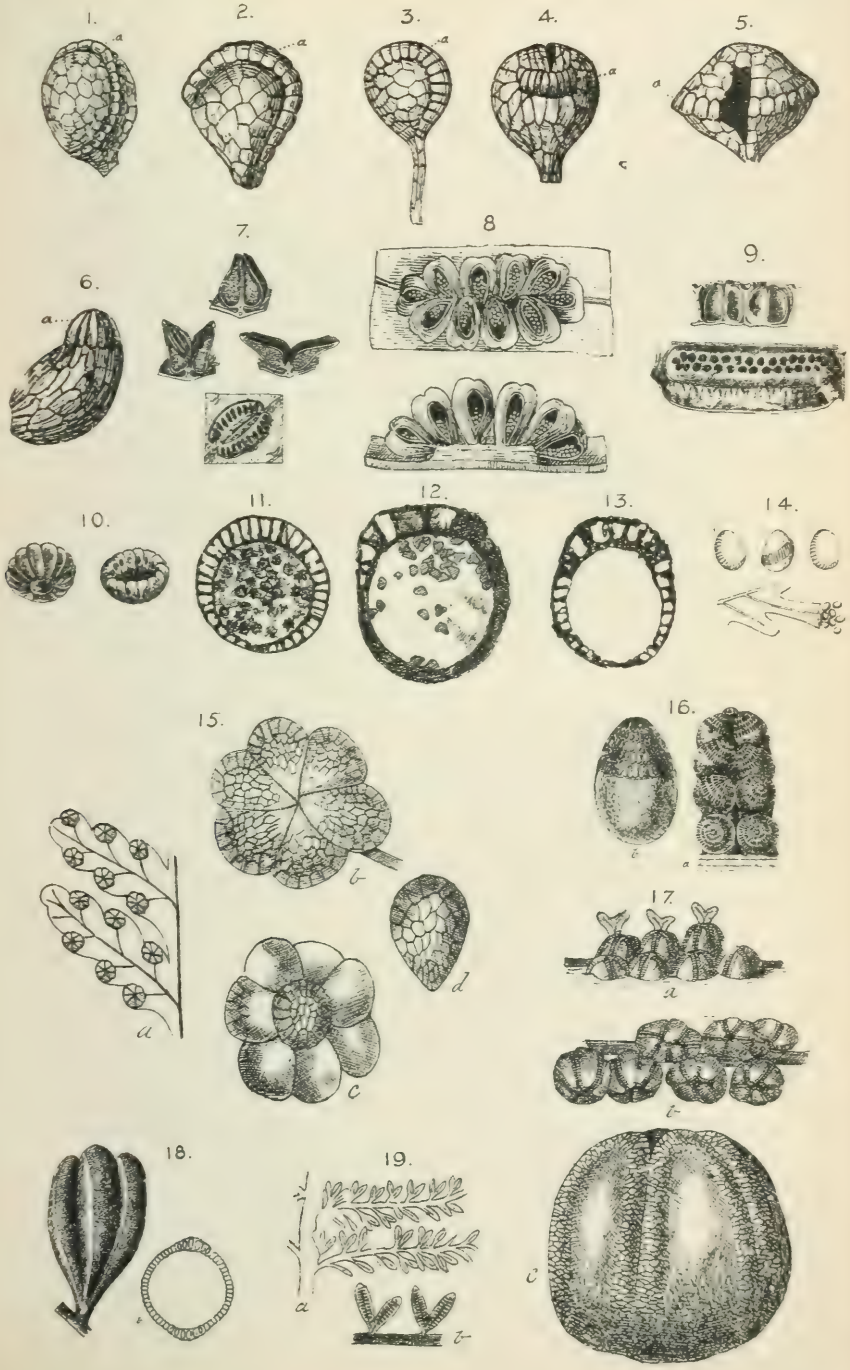
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Plate II.

Fig. 20.—*Scolecopteris*. *a. b. c. S. polymorpha*, Brongt., sp. *a.* Side view of synangia; *b.* transverse section of pinnule showing synangia; *c.* section parallel with surface of frond, showing arrangement of synangia. After Grand 'Eury. *d. e. Scolecopteris elegans*, Zenker. Transverse sections of fruiting pinnules. After Strasburger.

,, 21.—*Asterotheca abbreviata*, Brongt., sp. (= *Pecopteris Miltoni*, *Artis*). *a.* Portion of fruiting pinna; *b.* sporangia (both enlarged). After Zeiller.

,, 22.—*Ptychocarpus unitus*, Brongt., sp. *a.* Fruiting pinnules, the synangia bent over by pressure (enlarged); *d.* section of synangium. After Zeiller; *b.* fruiting pinnules seen from above; *c.* synangia seen from the side. After Grand 'Eury.

,, 23.—*Calymmatotheca*. *a. b. C. affinis*, L. and H., sp.; *c. d. C. bifida*, L. and H., sp.; *a. c. d.* (reduced); *b.* (enlarged to show the sporangia).

,, 24.—*Crossotheca Schatzlarensis*, Stur, sp. *a.* (reduced); *b.* synangium (enlarged); *c. Crossotheca Crepini*, Zeiller (enlarged). After Zeiller.

,, 25.—*Renaultia microcarpa*, Lesqx., sp. *a. b.* Fruiting pinnules; *c.* sporangium (all enlarged.)

,, 26.—*Dactylotheca dentata*, Brongt., sp. *a.* Fruiting pinnules; *b.* sporangium (all enlarged). After Zeiller.

,, 27.—*Cyclotheca biseriata*, Kidston. *a.* (reduced); *b.* sporangia (enlarged).

,, 28.—*Myriotheca Desaillyi*, Zeiller. *a.* Pinna bearing fructifying pinnules; *b.* two sporangia (enlarged). After Zeiller.

,, 29.—*Sphyropteris obliqua*, Marrat., sp. Fruiting pinnule (enlarged), (the sporangia are only shown on the right half); *b.* sporangium (enlarged).

,, 30.—*Urnatopteris tenella*, Brongt., sp. *a.* Fruiting frond (reduced); *b.* sporangia (enlarged).

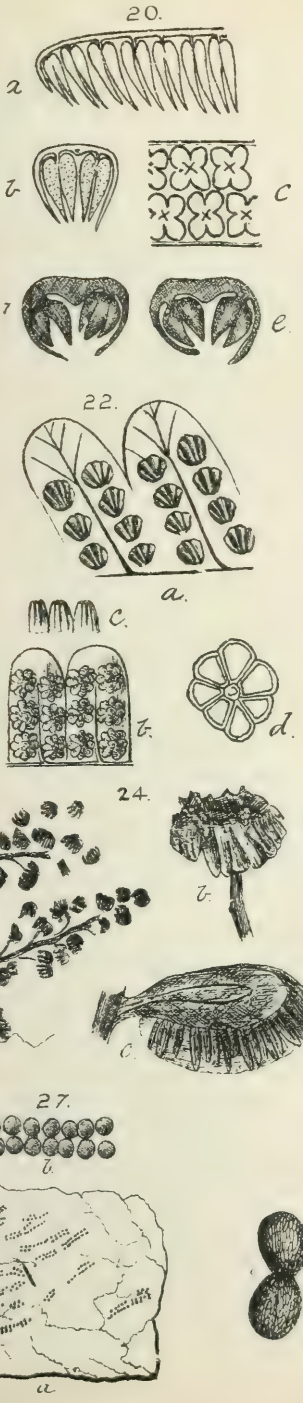
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Plate III.

Fig. 31.—*Palæopteris Hibernica*, Forbes, sp. *a.* Portion of fruiting pinna (reduced); *b.* fruiting pinnule; *c.* a few sporangia borne on the margin of a foliage pinnule; *d.* sporangia (enlarged). From specimens in the collection of the Geological Survey of Ireland, Dublin.

,, 32.—*Palæopteris Hibernica*, Forbes, sp. Base of a frond showing the stipules (much reduced). From a specimen in the collection of the Geological Survey of Ireland, Dublin.

,, 33.—*Unatheca oblonga*, Kidston. Two fruiting pinnules (natural size), and sporangium showing the longitudinal cleft (enlarged).

,, 34.—*Zeilleria delicatula*, Sternberg, sp. *a. b.* (Natural size); *d.* involucre (enlarged); *e. Zeilleria Avoldensis*, Stur, sp.

,, 35.—*Chorionopteris gleichenioides*, Corda. *a.* Vertical section of a capsule showing the sporangia containing the spores; *b.* exterior view of a closed capsule; *c.* longitudinal section of a fertile pinnule. After Corda.

,, 36.—*Neuropteris heterophylla*, Brongniart. Showing the fruiting portion, at the base of which are some barren pinnules (reduced).

,, 37. *Calymmatotheca asteroides*, Lesqx., sp. Portion of a pinna showing four groups of sporangia (slightly enlarged). And a sporangium (much enlarged). After Zeiller.

,, 38. *Caulopteris anglica*, Kidston. Showing the peltate scars with the inner horse-shoe-shaped vascular impression (reduced).

,, 39.—*Megaphyton MacLayi*, Lesqx., showing the vertical row of frond scars and the vascular impressions (reduced). After Zeiller.

,, 40.—*Psaronius Cottai*, Corda. Transverse section of portion of stem, showing central vascular axis of strap-shaped bundles, surrounded by parenchyma containing numerous rootlet bundles. After Schimper.

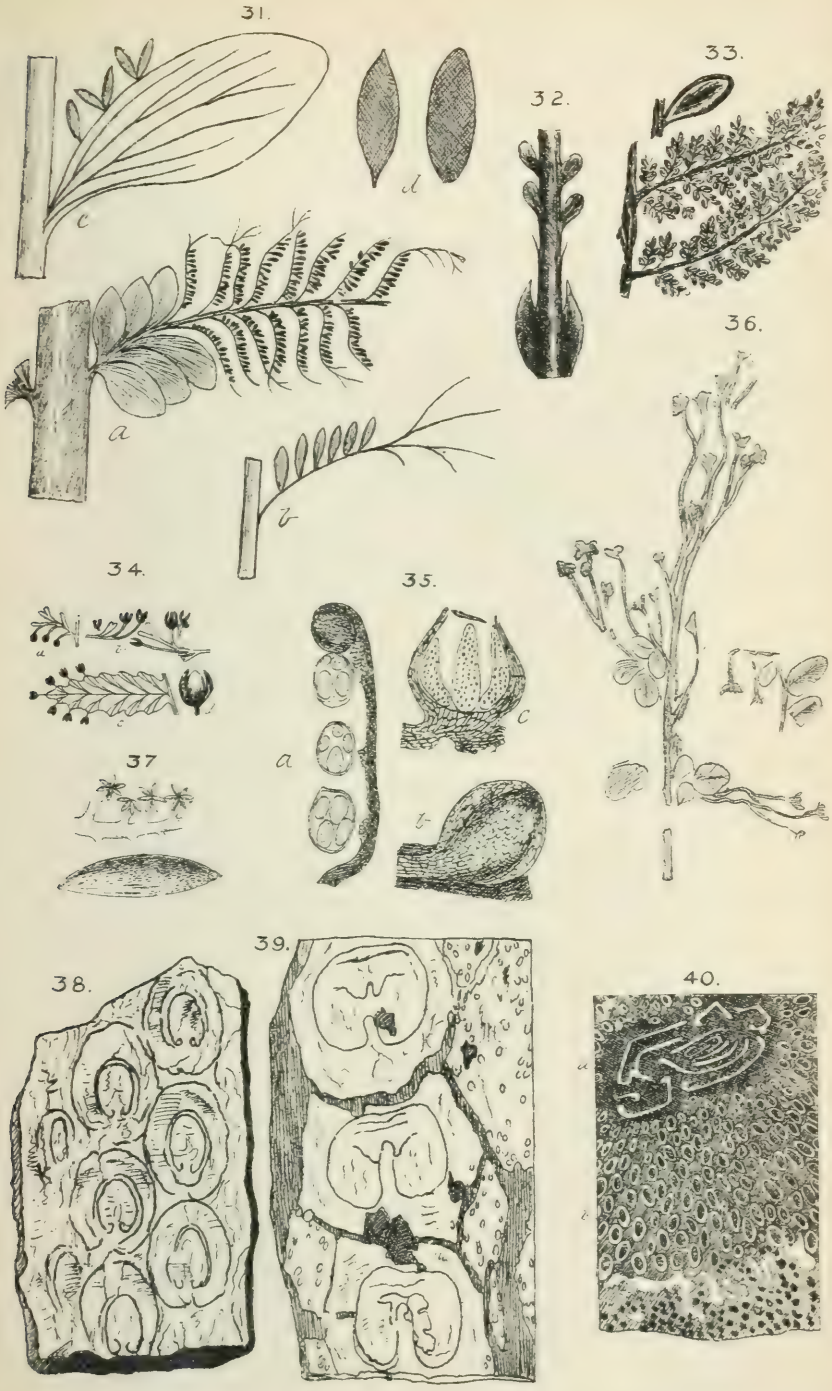
31.
c
d
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Plate IV.

Fig. 41. *Rachiopteris Lacattii*, Renault, sp. Portion of a transverse section of the rachis (enlarged).
a. Xylem portion of bundle.
b. Phloem portion of bundle.
c. Sieve tubes (?)
d. Bundle sheath.
e. Bundle going off to secondary rachis.
f. Outer bark.
Coal Measures, Halifax. (From a photomicrograph.)

,, 42. *Dictyoxylon Oldhamium*, Binney, sp. Transverse section of portion of a stem (enlarged).
a. Medullary axis.
b. Medullary rays.
c. Vascular tissue.
d. Stem bundle.
e. Parenchymatous tracts of bark.
f. Prosenchymatous tracts of bark.
g. Medullary vessels.
Coal Measures, Halifax. (From a photomicrograph).

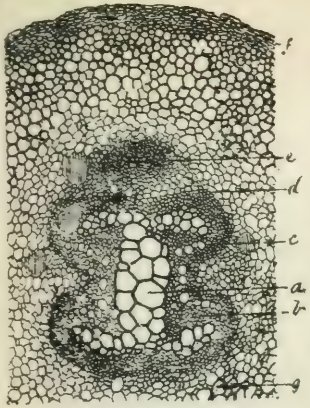
,, 43.—*Dictyoxylon Oldhamium*, Binney, sp. Outer surface of the stem. After Williamson (reduced).

,, 44. —*Sphenopteris Höninghausi*, Brongt. Portion of the rachis showing the outer surface bearing rhomboidal elevations, in the centre of which is a small dot, from which the spine-like scale has fallen. Middle Coal Measures, Netherton, Staffordshire. (From a photograph, slightly enlarged).

,, 45.—*Myelopteris*. Vascular bundle, transverse section.
a. Xylem portion of bundle.
b. Phloem portion of bundle, most of which has disappeared.
c. Ground tissue of stem.
Coal Measures, Oldham. (From a photomicrograph, enlarged).

,, 46.—*Ophioglossum vulgatum*, Linn. Vascular bundle, transverse section.
a. Xylem portion of bundle.
b. Phloem portion of bundle.
c. Ground tissue of stem.
(From a photomicrograph, enlarged).

41.



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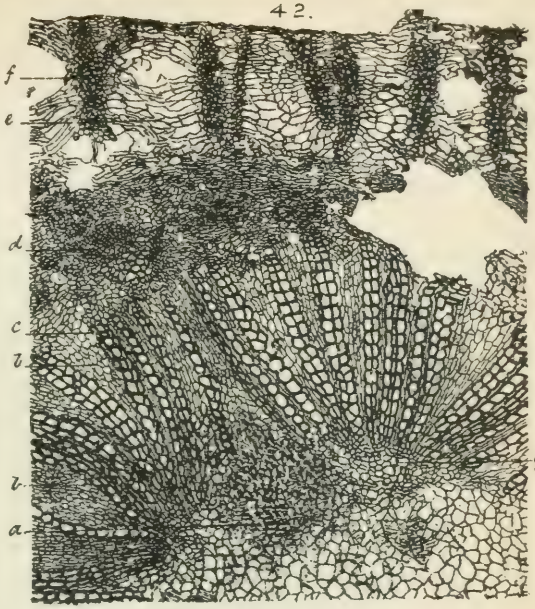

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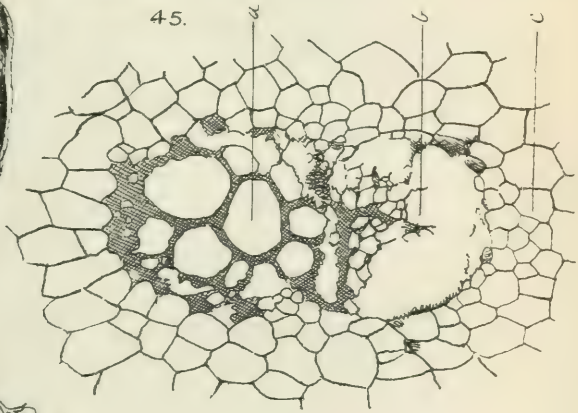

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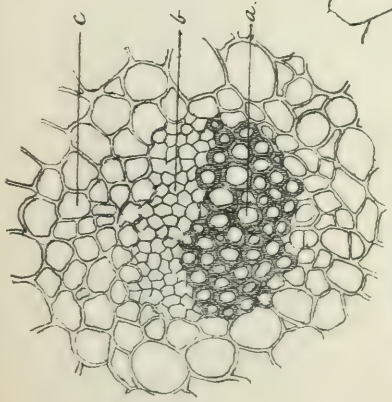

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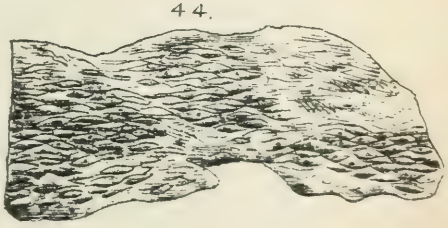


No. II.—On the Internal Structure of the Carboniferous Corals forming the Genus *Chætetes* of Fischer.

By John Young, F.G.S., *V.P.*

[Read 26th May, 1890.]

The genus of Carboniferous corals, forming the *Chætetes* of Fischer, has long been known to palæontologists under, at least, three generic names, viz., *Favosites*, *Chætetes*, and *Alveolites*. They were first described by Fleming, in 1828, in his "British Animals," where he placed them in Lamarck's genus, *Favosites*. In 1837, Fischer established the genus *Chætetes* for a Russian Carboniferous coral—*C. septosus*, now believed to be identical with one of Fleming's species. Count Keyserling, in 1846, removed Fleming's species from *Favosites*, from their not having perfect walls for their corallites, and from the absence of *mural pores* in their walls as found in *Favosites*, and placed them with Fischer's *Chætetes*. In 1851, Professor M'Coy, in his "British Palæozoic Fossils," accepted Fischer's genus for Fleming's species, but in the same year, Milne Edwards and Jules Haime, in their Monograph on "Fossil Corals," issued by the Palæontographical Society, removed Fleming's species from *Chætetes* into *Alveolites* of Lamarck, retaining at the same time Fischer's genus *Chætetes* for his species *C. radians*, which, as above stated, is now believed to be identical with Fleming's British form—*C. septosus*. *Chætetes*, however, is now the genus most generally accepted by palæontologists for this entire group of Carboniferous corals.

During last year, I was led to make an independent examination of the structure of these corals, by means of transparent sections prepared by myself for examination under the microscope. I was induced to do this, owing to a somewhat bitter dispute which had arisen between Mr. James Thomson, F.G.S., of this Society, and Professor H. Alleyne Nicholson, of the University of Aberdeen, as to the presence, or absence, of what are termed *mural pores* in the walls of these corals. Mr. Thomson—in the *Proceedings of the Philosophical Society of Glasgow*, 1881 and 1888—has figured and described what he terms *mural pores*, of the same character as those found in the genus *Favosites*, in our Carboniferous *Chætetes* (or *Alveolites*, as he prefers to name it).

Professor Nicholson, on the other hand, denies the existence of these mural pores in Mr. Thomson's specimens, and states—in the

Geological Magazine, vol. v., 1888, p. 110—"I have failed to find in a single instance any indication of any of the phenomena above-mentioned, as caused by the presence of mural pores. I have therefore no doubt that the corallites in the four species [mentioned by Mr. Thomson] possessed imperforate walls."

Mr. Thomson in his later paper (1888), above noted, re-asserts the existence of mural pores, and quotes Milne Edwards and Haime in support of his views, that the Carboniferous *Alveolites* "agree with Edwards and Haime's description, in possessing mural pores." I find, in referring to the Monograph of these authors, already noted, that while they place both *Chætetes* and *Alveolites* in Lamarck's family of the Favositidæ, yet neither in their descriptions of these genera, nor in those of the Carboniferous species, do they make any reference to the existence of mural pores in these corals, nor do they figure them in any of their illustrations. I may also state that, while they figure and describe mural pores in nearly all the species of *Favosites*, they omit them in their general description, as being in no way characteristic of all the genera now placed in the family of the Favositidæ.

I have no wish to make any other remarks on the points under dispute between Professor Nicholson and Mr. Thomson, except by stating that, so far as I have carefully sectioned and examined these corals, from the several districts of Scotland and England from which I have obtained specimens, I have failed in finding in their walls any traces of mural pores such as are characteristic of *Favosites*, or such as are figured by Mr. Thomson in his papers already quoted. I am, therefore, strongly inclined to agree with Professor Nicholson's opinion, that such mural pores do not exist in our British Carboniferous *Chætetes*.

I am, however, glad to be able to state that I have discovered, in the course of my investigations, that these corals possess an interesting internal structure of a different kind from that of the mural pores which characterise some of the genera forming the Favositidæ. This structure, which I have been fortunate in finding, exists only in well-preserved examples of the coral, and, so far as is known to me, has never hitherto been either figured or described. Briefly it consists of a numerous series of small short spines of varying lengths, which are seen to be planted in the walls and tabulæ of the corallites. Those on the walls project slightly outwards and upwards, whilst those on the tabulæ stand in a more or

less erect position. None of the spines, within the area of the corallites, seem to have extended in length beyond the distance that separates one cross tabula from another. I have further discovered that these spines, in the better preserved specimens, were not solid, but tubular, and, when cut in cross section, their interiors are seen to be filled with a clearer calcite than that forming their walls. The first specimen which afforded me this new insight into the internal structure of *Chætetes* I owe to the kindness of Mr. John Angus, Irondale House, Muirkirk, from the limestone strata of which district it was obtained. It came to hand after I had sectioned many specimens from other localities, and in which I had failed to find mural pores, or other structure different from that already figured and described in connection with *Chætetes*.

This discovery encouraged me to go on making sections from all available specimens, so as to get a better idea of the state of preservation of the structure in these corals from the various localities. For the opportunity of doing so I am indebted to Dr. J. R. S. Hunter of Braidwood, and to Dr. D. Forsyth, who supplied specimens from the Muirkirk district; to Mr. Robert Craig, Langside, Beith, for specimens from the Ayrshire limestones; to Mr. James Bennie, of the Geological Survey, for specimens from the Bathgate and Dunbar limestones; and to Professor Alleyne Nicholson for specimens from the Shap Fells limestone. To these gentlemen, therefore, I severally return my best thanks.

I have now prepared, from these specimens, over 100 sections, cut in transverse and vertical directions, and a careful study of them clearly shows that in them are to be found nearly all the stages of preservation of the coral, from the most perfect condition in which the spine structure has yet been found, as in Mr. Angus's specimen, down through a series in which the internal structure has become more and more obliterated, until all trace of spines, and even of tabulæ within the walls of the corallites, has disappeared. The causes which have led to this obliteration of the finer structures of the coral may have been various. They may have been due to the percolation of waters through the porous mass ere fossilization had taken place, or to after changes through mineralization of the strata in which the organisms were embedded. I am, however, inclined to think that the greater part of the obliteration of the finer structures took place during the life of the later-growing portions of the coral, for, in all the specimens yet sectioned, I have

only found the spine structure well preserved in, or near, the last-growing surface layers of the coral. Sections taken below this point show the spines gradually disappearing from the walls and tabulæ, till at the base and centre of the coral they are often entirely obliterated; or when traces of them are present, only the spine bases are preserved, appearing in the walls as a series of small dots, which, when viewed under the microscope by transmitted light, look like dark spots, or like white spots by reflected light. Had obliteration of the spine structure not taken place until after the final death of the outer-growing portions of the coral, it would have been difficult to explain why the outer surface layers have the structure better preserved than those of the interior, for if the obliteration was entirely due to fossilization, or to other mineral changes after death, one would naturally expect the outer surface would have been first affected. This, however, is seen not to be the case.

In some localities *Chætetes* is often found in a more or less silicified condition. When this is the case, the internal structures have generally suffered great alteration, both spines and tabulæ being obliterated. In such silicified specimens we sometimes find that the walls of the corallites have been wholly or partly replaced by silica, which has been deposited on the walls, in the form of numerous minute, rounded "blebs" or dots of microscopic size, and slightly raised above the surface of the walls. Those who are in search of mural pores in this coral might readily mistake these raised points of silica for the openings of pores, and possibly they have been mistaken for such, but microscopic sections clearly show that they never were pores, but mere incrusting points of silica, having a ring-like structure, and of the chalcedonic type. I may here mention that all the better-preserved specimens of *Chætetes* seem to have been enveloped in a calcareous shale, whilst those found in the purer limestones have had their structure more or less obliterated through crystallization of the limestone. This condition of preservation seems to hold good in the case of the other Carboniferous organisms which I have sectioned, the finer structures being generally obtained from the shale beds of the limestone series.

Having thus briefly indicated some of the conditions under which these corals have been found, and that the finer structures seem to have been very perishable, and are seldom preserved, I

shall now shortly point out those characters found in well-preserved examples, both on the surface and in the body of the structure. In the Muirkirk specimens preserved in shale, examples often turn up showing the polygonal cell-openings of the corallites on their outer surface, and, where such cells have been cleaned out by weathering, their boundary walls can usually be examined. These are seen to have originally had a loosely porous and spinose structure, and are now, in the better-preserved examples, clad with a numerous group of minute and slightly-raised tubercles—the bases of spines—which give to the outer margin of the cell-walls a roughened appearance, reminding one of the slightly-raised acanthopores found on the surface of some forms of the Monticulipora. Where this structure on the surface of *Chætetes* has been well preserved, the tubular character of the spines planted in the walls and tabulæ is best seen in transverse sections which have been cut at, or close to, this later-growing surface. As already stated, the spine structure is absent from the deeper portions of the coral, or is more or less obliterated, even in specimens where it is well preserved at the surface. In transverse sections, the number of spines found on the walls and tabulæ within the area of each corallite is very variable. In some a hundred or more may be counted, in others less than a dozen, but this decrease in numbers of the spines in any of the corallites, is due, I think, more to their obliteration after death than to their non-existence in life, for the best sections show clear evidence that in the living condition of the coral both walls and tabulæ were crowded by a structure of minute spines. As the tabulæ do not always occur on the same level in the corallites, transverse sections, therefore, never show more than those few with their spines which chance to be at the surface. In vertical sections the spines, as now preserved, are seen to be of varying lengths, both on the walls and tabulæ, but, owing to their being cut chiefly longitudinally, their tubular character is not so conspicuously visible as in the transverse sections, though their slanting bases, where they pass into the walls, can be seen as groups of small dark spots, from their slightly-denser structure. Another character, in many of the vertical and transverse sections, is the thickening of the walls of the corallites in parts by a secondary deposit of sclerenchyma. This is now chiefly found near the outer surface of the coral, and, when well preserved, the tubular spines are there seen to have existed in great numbers. Deeper down in

the coral, the sclerenchyma often seems to have been dissolved away, evidently by the action of those agencies which, as already indicated, have obliterated all traces of spines and tabulæ. When this is the case, the walls of the corallites, in the deeper parts of the coral, look thin and naked when compared with sections cut near the surface, where the sclerenchyma and clothing of spines exist.

The evidence of the disappearance of structure, such as spines and tabulæ, from within the walls of the corallites, which is afforded by my various sections, will help to explain statements made by some former observers, such as that the tabulæ were often absent, rare, or remote, or that they had apparently never been developed. In some of these sections the total and partial disappearance of the tabulæ from within the walls of the corallites can be distinctly seen within certain altered areas of a single specimen.

The only other structural character which I have to note in connection with this coral is one seen in some of the better-preserved Muirkirk specimens. It consists of a system of minute thread-like canals which traverse the walls in a horizontal, wavy manner, and which are of a lighter colour than the calcite forming the walls; but whether this appearance is to be considered as the remains of a minute structure which once pervaded the walls is a point on which we require further enlightenment. Some of the sections from these specimens also show, that, during the growth of the coral, it was often infested by various other incrusting organisms of the limestone period, and which are found as thin patches between the layers of growth in the coral. They belong to three distinct organisms, viz., *Tabulipora Urei*, *Fistulipora incrustans*, and a minute, twisted, tubular organism which closely resembles *Girvanella*, a genus not yet recorded from the Carboniferous strata of Western Scotland. These incrusting organisms have evidently, for a time, caused interruptions to the growth of the living coral over the areas of surface to which they were attached, but in their turn they are seen to have been buried under the outer growths of the newer layers of the coral.

From what I have stated in the foregoing remarks regarding the structure found in the better-preserved examples of *Chætetes*, it will be seen that we have here an organism, in the walls of whose corallites there is an entirely different structure from that of the horizontal mural pores characteristic of *Favosites*, or of those which

have been figured and described by Mr. Thomson as found in the Carboniferous *Chætetes*, but of which no corroborative proof seems to exist. The only other Carboniferous organism with a somewhat similar structure and arrangement of spines within the walls of its corallites, is, so far as I know, that of *Fistulipora incrustans*, Phill. (*F. minor*, M'Coy). This new structure in *Fistulipora*, I have, however, already noticed in a paper in the *Annals and Mag. Nat. Hist.*, April 1888, pp. 244-5.

I shall now conclude this paper by stating that some three or four species of *Chætetes* from Carboniferous strata have been described, but it is very probable that these are no more than varieties of one and the same coral produced by the more or less favourable conditions under which they lived. *Chætetes radians*, Fischer, is now believed to be identical with *C. septosus*, Flem., while, according to Professor M'Coy, *C. depressus*, Flem., is only a dwarfed condition, owing to slower growth of the same coral, its corallites, within a certain area, being more numerous and smaller than those of *C. septosus*, which is the only well-marked difference between the two species. In the sections which I have prepared there are considerable differences, both in the form and size of the corallites, even within the area of the same specimen when that happened to be large, but the spiny structure of the walls and tabulæ present the same characters in all the varieties—of which *C. septosus*, Flem., may be taken as the more common type.

No. III.—Notes upon a Cutting in the New Kilbirnie Branch of the Lanarkshire and Ayrshire Railway, on the Farm of Gurdy, Beith. By Robert Craig, Langside, Beith, *Corresponding Member.*

[Read 13th December, 1888.]

Introduction.—The cutting on the above-named railway to which I wish to direct your attention is on the farm of Gurdy, Beith. It commences near where the railway crosses the Beith and Kilbirnie road, and extends for about three-fourths of a mile in an east-by-south direction, finally running out on the farm of Coalburn, Dalry. The greatest depth is on Gurdy farm, where it is nearly 30 feet deep; and as it intersects the strata at an oblique angle, it has cut through and exposed from 20 to 25 fathoms of the strata which lie above the lower limestone and below the workable clayband ironstone. The intersection of these strata is at the west or Kilbirnie end of the cutting, and terminates at a fault and downthrow where it crosses the Kerrsland glen and Pogree burn. The strata met with in the cutting, from this burn to its termination on Coalburn, belong to those which lie above the main coal of the Dalry field. Except vegetable markings, the sandstone and shales on the east end of the cutting are apparently non-fossiliferous.

The mineral and fossiliferous characters of the strata west of the Pogree burn have been closely anticipated in a previous paper by the author, "On the Strata between the Lower and Upper Limestones" (*Transactions*, vol. vii., page 86). In that paper is given a section of the strata exposed in Kerrsland glen, and in the Gurdy railway cutting the same strata are found. In the following notes regarding them I shall, where they correspond, give also the numbers by which they were distinguished in the glen section above mentioned.

Limestone no. 1; Glen section no. 11.—A few yards from the west end of the cutting a bed or band of limestone was laid open continuously for about 30 yards; at this point dipping below the level of the excavation. This thin band of limestone, 1 foot 4 inches thick, differed little from that in the glen. The shale attached both to its upper and lower surfaces was a mass of crushed organic remains, and yielded some good cabinet specimens. The purer limestone of the band itself was not rich in the number

of its fossils, though it held a few similar to those got in the attached shales. The principal shell remains found both in the limestone and shales were as follows:—a variety of *Productus longispinus*, Sow., which was abundant, and continued so in the overlying shales and thin limestone bands throughout the cutting; *Productus scabriculus*, Mart., was rare; two specimens of *Productus plicatilis*, Mart., were found in the cutting, thus adding others to the single specimen of this shell described in my former paper as found in the same band in Kerrsland glen. A few specimens of *Cardiomorpha oblonga*, Sow., were found in the limestone, and *Cypricardia rhombea*, Phill., was not rare in the overlying shale. In the shales below and above the limestone band, *Orthis Michelini*, L'Eveille, was abundant, and also a few specimens of *Orthoceras*, but all very fragile.

Shale; Glen section no. 13.—Resting upon the above band of limestone, as found in the cutting, was seen a series of layers of shale 28 feet in thickness, though only about 13 feet thick in the glen. These shales are full of shell remains, but so much crushed that good cabinet specimens are rather rare. Their lower part is calcareous and rich in remains of the above-mentioned shells. In addition to them, *Spirifera trigonalis*, Mart., *Rhynchonella pugnus*, Phill., and *Reticularia (Spirifera) lineata*, Mart., were found; *Nucula gibbosa*, Flem., was abundant, along with *Nuculina (Leda) oblonga*, M'Coy: and *Schizodus (Axinus) deltoideus*, Phill., was plentiful, and continued so in all the fossiliferous strata throughout the cutting. A few Gasteropods were also found, *Macrochilina (Macrocheilus) acutus*, Sow., being most abundant. About the middle of these shales they become almost unfossiliferous for a few feet and more clayey in character; but again turn calcareous, until they are capped by another band of limestone, which is very fossiliferous. In the upper portion some of the bands are made up of crushed shell remains. Of these *Leptodomus costellatus*, M'Coy, is prominently abundant, being also found in the shale above the band of limestone presently to be described. A large number of fine specimens of this shell were found in the cutting, some of larger size than obtained elsewhere.

Limestone no. 2; Glen section no. 14.—This limestone was $2\frac{1}{2}$ feet thick in the cutting, being about 2 inches less in the glen. The limestone itself is not rich in organic remains, excepting the stems of a small Crinoid, which, in a large measure, make up its

bulk. In a thin bed of calcareous shale, upon which this limestone rests, fossils are abundant; some parts being one mass of a small Gasteropod, *Loxonema curvilinea*, Phill. The shells found in the shale below, and noticed above, are abundant. In addition to these, *Naticopsis canaliculata*, M'Coy, and *Natiria (Naticopsis) lirata*, Phill., were found, but not abundantly. A few specimens of *Ptychomphalus (Pleurotomaria) monilifera*, Phill., and one specimen of *Agnesia (Pleurotomaria) contraria*, de Kon., were got. *Entalis (Dentalium) inornatum*, M'Coy, was abundant, and *E. priscum* (?) Goldf., was common, but very fragile. This species was of large size, some specimens being 4 inches in length and many of them 3 inches long, though entire specimens could not be procured, from the indurated character of the shale and fragile nature of the shell. In this shale and in all the shales in the cutting, *Bucania (Bellerophon) decussata*, Flem., and *Euphemus (Bellerophon) Urei*, Flem. were in abundance; and associated with them was a small Lamellibranch, *Nucula lineata*, Phill., rather abundant, but confined to this shale alone so far as my observation went.

As already mentioned, the bed of limestone was poor in shell remains. The calcareous shale that rested upon it contained the same species as the shale below it, and in general held them in the same rich proportions; except the above-named *Nucula lineata* and *Loxonema curvilinea*, which were not found in the shale above the limestone band.

Shales; Glen section nos. 15 and 16. These shales, resting upon the limestone here described, have a combined thickness of 20 feet. For about 12 feet above the limestone they are slightly calcareous, and rich in organic remains. Above this they become carbonaceous and unfossiliferous. In the lower part shells are found similar to those already mentioned, and generally in bands, some of which are very rich in examples of *Leptodomus costellatus*, M'Coy. In addition to the fossils mentioned, the following genera and species of Ostracoda were common in most of the fossiliferous shales in the cutting, being also found in all the fossiliferous bands in the ironstone measures in this locality:—they were, *Cythere* (?) *Bairdioides*, J. and K., *Beyrichia subarcuata*, J. and K., and *Leperditia Youngiana*, J. and K. While the limestones and their associated shales were rich in shell remains, they were very poor in those of Fish. A fragment of a tooth of *Cladodus mirabilis*, Ag., and one

tooth of *Petalodus Hastingsiæ*, Owen; a small tooth of *Helodus didymus*, Ag., with a few single scales of *Megalichthys Hibberti* (?) Ag., were all that came under my observation.

Sandstone.—These shales were capped by a thin bed of hard sandstone, 3½ feet thick in the cutting, and 4 feet 3 inches in the glen. It held a few fragments of *Stigmaria*, but otherwise was unfossiliferous. Above this lay a few feet of sandy shale, unfossiliferous except that it held a few vegetable markings too obscure for identification.

Limestone no. 3; Glen section no. 19.—This limestone is 3 feet thick in the cutting, and 5 inches less in the glen. It lies about 6 fathoms below the main clay ironstone, and is found extending throughout the district. It is rich in shell remains, though it produces few specimens fitted for the cabinet. It has a peculiarity of character unique in the locality, and this holds good wherever it is found. Like other thin bands in the ironstone measures, it is not a good carbonate of lime, being little better than a calcareous shale; and the shells that it holds are all broken into fragments. It has the appearance of having been highly crushed while in a soft state, the broken fragments of shells being mixed and pressed together in a confused manner, which gives it a curious flecked and baked-like appearance. It is very rare to find even a single valve quite perfect, and it will thus be seen that good specimens cannot be expected. However, from the larger pieces of the broken shells, they appear to belong to the same genera and species as those found in the lower bands of limestone and shales in the cutting, which are described above. I did not get this band so closely examined as I had intended, so that the list appended is not so full as it might have been: but all those which have been identified from it are inserted in the list.

At the point of the cutting where this band dips below the level of the railway, and where the line crosses the Kerrsland glen and Pogree burn, a fault of nearly 50 fathoms occurs, running from a north-east to a south-west direction. It is an upthrow to the west, bringing the strata exposed in the cutting on a level with a sandstone which lies above the Dalry main coal. From here the cutting runs in this sandstone and along a small basin of the Dalry main coal, preserved as an outlier in a hollow by the fault, and which was worked out about fifty years ago. There

was little palæontologically interesting in the sandstone; a few *Stigmaria* markings were found, and in the sandy shales, interbedded with the finer sandstone, Plant remains were plentiful, though too obscure for identification. *Calamites Suckovii*, Brongn., and *Cordaïtes borassifolia*, Sternb., were common, particularly the latter, and were the best preserved of the plant remains.

After crossing the road from Beith to Dalry, the cutting runs through a few beds of flaggy sandstones and shales which crop up from under the above sandstone. These rise to the east, or in the same direction that the cutting runs. About 200 yards east of the road the cutting is continued in surface beds, and soon runs out. Nothing of interest was found in this end; the large fault that crosses it, at the point where it intersects the Pogree burn, bringing the fossiliferous strata to a close. The few vegetable remains in the shales and flaggy sandstones, were too obscure for correct identification.

In conclusion, I may state that while the list of fossils here appended contains all that came under my own observation, it is not to be accepted as a complete list of all that the fossiliferous strata hold. From what was noticed, under better preservation a number of genera and species might have been added, especially to the list of Pectens. The specimens of this class were, mostly, so crushed and mutilated that nothing could be done with them.

I have again to thank my friend Mr. John Young, F.G.S., for his kind assistance in identifying and naming all fossils which I felt uncertain about.

On the following pages will be found the list of the fossils above referred to, their occurrence being grouped under three divisions —No. 1, those from the limestone and shale in Gurdy cutting, corresponding to the beds Nos. 11 to 13 in Kerrsland glen; No. 2, those from the limestone and shale in the cutting, corresponding to Nos. 14 to 16 in Kerrsland glen; and No. 3, those from the limestone and shale in the cutting, corresponding to Nos. 19 and 20 in Kerrsland glen.

LIST OF FOSSILS IN GURDY CUTTING, KILBIRNIE BRANCH, LANARKSHIRE AND AYRSHIRE RAILWAY.	No. 1 Limestone and Shale in cutting; nos. 11 to 13, Kersland glen.	No. 2 Limestone and Shale in cutting; nos. 14 to 16, Kersland glen.	No. 3 Limestone and Shale in cutting; nos. 19 and 20 Kersland glen.
ACTINOZOA.			
Tabulipora (*Stenopora*) *Urei*, Flem.	x	x	x
Zaphrentis cylindrica (?), Scouler.		x	
ECHINODERMATA (Crinoidea).			
Platycrinus laevis, Miller.		x	x
Poteriocrinus crassus, Miller.	x	x	x
Rhodocrinus uniarticulatus, de Kon.		x	
ANNELIDA.			
Serpulites carbonarius, M'Coy.		x	
Spirorbis Armstrongi, Etheridge.		x	
CRUSTACEA (Ostracoda).			
Cythere (?) *Bairdioides*, J. and K.	x	x	x
Beyrichia subarcuata, J. and K.		x	
Leperditia Youngiana, J. and K.	x	x	x
POLYZOA.			
Fenestella plebeia, M'Coy.	x	x	
Polypora dendroides, M'Coy.		x	x
BRACHIOPODA.			
Athyris ambigua, Sow.	x	x	x
,, *planosulcata*, Phill.		x	
Discina nitida, Phill.	x	x	x
Lingula mytiloides, Sow.	x	x	x
Orthis Michelini, L'Eveille.	x	x	x
Productus longispinus, Sow.		x	
,, *var.* (?).	x	x	x
,, *plicatilis*, Mart.	x		
,, *scabriculus*, Mart.		x	
,, *semireticulatus*, Sow., *var.* Mart.		x	
,, *Youngianus*, Davidson.		x	
Rhynconella pugnus, Phill.	x		
Spirifera trigonalis, Martin.	x	x	
Martinia (*Spirifera*) *Urei*, Flem.		x	
Reticularia ,, *lineata*, Martin.		x	
Dielasma (*Terebratula*), *resicularis*, de Kon.		x	

LIST OF FOSSILS IN GURDY CUTTING, KILBIRNIE BRANCH, LANARKSHIRE AND AYRSHIRE RAILWAY—(*Contd.*)	No. 1 Limestone and Shale in cutting; nos. 11 to 13, Kerrsland glen.	No. 2 Limestone and Shale in cutting; nos. 14 to 16, Kerrsland glen.	No. 3 Limestone and Shale in cutting; nos. 19 and 20, Kerrsland glen.
LAMELLIBRANCHIATA (Monomyaria).			
Aviculopecten calatus, M'Coy.		x	
,, *concentrico-striatus*, M'Coy.	x	x	
,, *interstitialis*, Phill.	x	x	x
,, *orbiculatus*, M'Coy.		x	
Entolium (*Pecten*) *Sowerbii*, M'Coy.	x	x	
LAMELLIBRANCHIATA (Dimyaria).			
Arca Lacordaireana, de Kon.	x	x	
Schizodus (*Axinus*) *carbonarius*, Portl.	x	x	
,, ,, *deltoideus*, Phill.	x	x	x
,, ,, *centralis*, M'Coy.	x	x	
Cardiomorpha oblonga, Sow.	x	x	
Cypricardia striato-lamellosa, de Kon.	x	x	x
,, *rhombea*, Phill.	x	x	
Edmondia oblonga, M'Coy.	x	x	
Leptodomus costellatus, M'Coy.	x	x	
Nuculina (*Leda*) *oblonga*, M'Coy.	x	x	x
,, ,, *attenuata*, Flem.	x	x	
Nucula gibbosa, Flem.	x	x	x
,, *lineata*, Phill.		x	
GASTEROPODA.			
Entalis (*Dentalium*) *inornatum*, M'Coy.	x	x	x
,, ,, *priscum*, Goldf.	x	x	
Polyphemopsis (*Eulima*) *Phillipsiana*, de Kon.		x	
Loxonema Lefebvrei, L'Eveille.	x	x	
,, *curvilinea*, Phill.	x	x	
Macrochilina (*Macrocheilus*) *acutus*, M'Coy.	x	x	x
,, ,, *fusiformis*, Sow.		x	
,, ,, *Michotianus*, de Kon.	x	x	
Naticopsis variata, Phill.	x	x	
,, *canaliculata*, M'Coy.	x	x	
Natiria (*Naticopsis*) *lirata*, Phill.		x	
Tychonia (*Naticopsis*) *Omaliana*, de Kon.		x	
Aclisina (*Murchisonia*) *quadricarinata*, M'Coy.		x	x
Agnesia (*Pleurotomaria*) *contraria*, de Kon.	x	x	
Ptychomphalus ,, *monilifera*, Phill.	x	x	
HETEROPODA.			
Bucania (*Bellerophon*) *decussata*, Flem.	x	x	x

LIST OF FOSSILS IN GURDY CUTTING, KILBIRNIE BRANCH, LANARKSHIRE AND AYRSHIRE RAILWAY—(*Contd.*)	No. 1 Limestone and Shale in cutting; nos. 11 to 13, Kerrsland glen.	No. 2 Limestone and Shale in cutting; nos. 14 to 16, Kerrsland glen.	No. 3 Limestone and Shale in cutting; nos. 19 and 20, Kerrsland glen.
HETEROPODA—*Continued.*			
Waagenella (*Bellerophon*) *Dumontii*, D'Orb.(?)		x	
Euphemus ,, *Urei*, Flem.	x	x	x
CEPHALOPODA.			
Orthoceras attenuatum, Flem.	x	x	
,, *undatum*, Flem.		x	
,, *cylindraceum*, Phill.	x	x	
,, *Goldfussianum*, de Kon.	x	x	x
Nautilus (*Discites*) *quadratus*, Flem.		x	
Poterioceras (?)		x	
PISCES.			
Cladodus mirabilis, Ag.	x		
Tomodus convexus, Ag.	x	x	
Helodus didymus, Ag.	x	x	
Petalodus Hastingsiæ, Owen.		x	
Megalichthys Hibberti, Ag.	x	x	x

No. IV.—On New Localities for Zeolites. By Professor M. Forster Heddle, M.D., F.R.S.E.

[Read 10th April, 1890.]

In those countries where minerals are either raised in mines along with metallic ores, or are themselves ores of metals, there should be no difficulty in fixing the locality which furnished them; and any intentional deception connected therewith cannot be but short-lived.

Where, however, they are obtained by search at escarpments or shattered cliffs, or laid bare in quarries opened for dyking or building purposes, there is every opportunity for concealment and deception at the time of the find, and a very great probability of the locality passing out of mind, either from the death of the original finder, or from the surface-weathering, if not the filling up, of the quarry.

In the "Manual of Mineralogy" of Messrs. Greg and Lettsom, the following species are stated to have been obtained from the Campsie Hills, in Stirlingshire:—natrolite, stilbite, heulandite, laumontite, analcime, harmotome, weissigite, prehnite, thomsonite, mesotype.

The statements regarding certain of these species are precise, even to the giving the dimensions of the crystals; while an exact locality—Fintry—is also sometimes specified.

For reasons immediately to be mentioned, the present writer—in revising in 1858 the proof sheets of the above-mentioned work—was desirous of attaching a mark of doubt in connection with this locality, in most if not in all of these cases; but Mr. Greg, finding the locality given in the catalogue of the specimens in the Allan Collection, decided to let the references stand unquestioned.

My doubts arose from three causes. The first was that I found that it was the practice of three peripatetic mineral dealers, who for some years visited Scotland, systematically to mislead their customers as to the localities of all home-found minerals. Two of the tracts of country to which purchasers were directed—on account of their great extent very far from happy hunting-grounds—were the Campsie Hills, and Dumbarton Moor.

So absolutely was this habit recognised as a principle of "business," that the writer was told by one of the above persons

that his business was "to sell, and not to tell." Even *purchased* information was found to be worthless.

The second cause was that several excursions made by myself among the Campsie Hills proved absolutely without result.

The third, however, had very much the greatest influence.

About the year 1849 I had the pleasure of making the acquaintance of Dr. Thomas Brown of Lanfine, Ayrshire, then in about his seventy-seventh year. Dr. Brown had then far and away the largest collection of minerals in Scotland; he was the contemporary of Macculloch, Thomas Allan, Fergusson of Raith, Sir Charles Geseikie, Thomas Thomson, and Robert Jamieson;—that coterie which was the parent of British mineralogy.

Dr. Brown, living in the district, had kept an eye upon everything that came in his way, and he had collected with his own hands.

One of the queries which I put to him, and that with some frequency, was as to the occurrence of the red stilbite, and red heulandite, in Campsie Fells,—as asserted by the dealers.

Dr. Brown assured me that he knew of no mineral locality in the Campsie Hills; and he stated that in the south-west of Scotland there was but one locality for the above two minerals. This was a quarry-hole opened in the avenue to Cochno House, Dumbartonshire, which quarry was, shortly after the metalling of the avenue, closed up by order of the proprietor—he being annoyed at the number of "vagrom" men who came about the place for bits of the red stones.

Shortly after this time a poor specimen of red stilbite was found by the writer at the Long Craig above Dumbarton; and, as the *red* variety of these two minerals is considered generally to be highly striking, and as such are perhaps the most showy minerals found in Scotland, I have made repeated search, both over the bleak and wearisome stretches of the Campsie Hills, and over the bleak and black and blasted elevated flat termed Dumbarton Moor. With a special view to these two red varieties, about a week was spent at Fintry, a few years ago. As regards the Campsie Hills, the results have been on every occasion a perfect blank. The writer can say that for 40 years not a mineral specimen (aside of jaspers and selenite) has come from these hills, while it is significant that during one or other of his visits to Bowling quarry (extending over a period of five-and-forty years) he has, *with the*

exception of these red varieties, found every one of the minerals which used to be assigned to the two above-mentioned tracts.

This finding is made more absolute by this—that Mr. John Young, F.G.S., of Glasgow University, who knows this district infinitely better than any one else, has frequently assured the writer that he never heard of any good mineral localities in the Campsie Hills proper; or at least of *zeolitic* localities.

But the lava-streams which form this elevated ridge are continued eastward to Stirling; and the stretch which lies eastward of the Fintry valley is not much smaller in extent than the western portion.

This eastern portion goes under the local names of the Boquhan, Gargunnock, or Touchadam Hills.

In the new "Statistical Account of Scotland," it is stated that some fine specimens of zeolite had been found from time to time on the hill to the north of Fintry.

The writer could find none on Stronend.

In the gap termed "The Double Crags" he found druses which contained only rosette crystals of dark saponite *(prasilite)* in calcite; in the banks of the Endrick small druses of saponite with natrolite; and on the southern slopes of Balhannan Hills, above the Walton reservoir, red heulandite in minute crystals.

There is no record anywhere as regards any other part of these hills; any new observation is thus *a new find*, and if it relates to the two red minerals, an important find.

Mr. Robert Kidston, F.G.S., of Stirling, and Colonel Stirling of Gargunnock, have hit upon three localities which yielded the red mineral or minerals, and one at least of these localities is very promising.

The specimens from the several finds were sent to the writer to name. Mr. Kidston wishes the localities to be recorded, but in refusing to allow his name to stand at the head of this notice, he declines to accept of any share of credit for that whereof the credit belongs to himself alone.

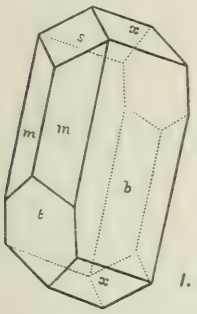
The first of these localities is on the north side of these hills. It was a loose block which lay at the height of 750 feet upon the west side of a spur of the Black Craig, near the head-waters of the Leckie burn. Mr. Kidston is satisfied that it was not a travelled block, but had simply fallen out of the cliff above.

The specimen consists of red stilbite in crystals which interlace

with one another. These crystals are from 2 to 3 inches in length. They lie upon zeolitic or radiating quartz. The interest of the specimen lies in this quartz. The zeolitic quartz associated with red stilbite elsewhere—wherever that is—is white, being, however, frequently rendered pinkish by interstitial radiating plumose natrolite. The quartz here is indigo-blue in tint.

The second locality is the cutting made for a dam embankment for a new reservoir in the Touch Hills near Stirling.

Here red stilbite of two varieties was found. The first is a druse lined with well-formed crystals of about $\frac{5}{8}$ of an inch in length, *a b r p*. The specimen is rather weathered, but fresh ones would be as good as any of the same dimensions got in the west of the country. The other variety is in large sheafy crystals like the specimen from Black Craig; but along with it there are minute crystals of red heulandite of the form drawn (Fig. 1), and rosette crystals of green saponite.



1.

The third locality is at Earlsburn reservoir, in Touchadam Moor. Like the last, the specimens here were got unfortunately just after the reservoir had been completed, and the greater part, and the best, had been carried off.

A box full of specimens was sent from this place. Though the condition of these was very unsatisfactory, yet there was not a specimen which did not give some information bearing upon zeolitic formation: and the interest was all the greater that the inferences to be drawn therefrom were different from, though perhaps not discordant with, those which present themselves at other zeolite-yielding localities.

The subject cannot be more than referred to here.

The rock is an amygdaloidal porphyrite, with pea- and bean-sized druses of all shapes. Many of these are filled with saponite, of a nearly white colour. Most of the crystals are labradorite, but there is a suspicion of sanadine also. While the crystals near to the surface of the specimens are altogether kaolinised, *many of those which are quite close to the margins of the larger druses are remarkably lustrous.* They thus seem *unchanged*: unless this

high lustre is the first stage in decay, as it often is in exposed crystals.

Some druses are totally filled by a radiating flesh-coloured mineral, which has assumed a solid appearance. This mineral may be natrolite. It is a little like lehuntite, but is more solid. I prefer to say I do not know it.

Brown göthite lines the cavities like a skin, about $\frac{1}{8}$ of an inch thick; over this there is sometimes analcime, sometimes harmotome; and over these milk-white quartz. Occasionally göthite, as rubinglimmer, is superimposed upon either the harmotome or the quartz.

In the larger cavities there are crystals of analcime over $\frac{1}{2}$ an inch in size, *n* and *u a*, covered by white quartz.

One specimen had a crystal of harmotome *a b p*, which was a *simple crystal*, with not a trace of striation upon *b*. This is the only simple crystal I ever saw of the mineral. But the specimen carried abundance of twin crystals, near the form of fig. 6 in Greg and Lettsom's "Mineralogy," differing only in having a narrow re-entering angle, and no face *s*. These are all striated on *b*.

In the larger crystals of analcime their centres are "cluthalite;" but there are specimens with small crystals which are deep red throughout.

The chief interest connected with this find of Mr. Kidston's relates to some minute crystals which lie in a cavity of a specimen which carries analcime and harmotome. These crystals are not $\frac{1}{4}$ of an inch in length generally not half that size. In colour, lustre, and transparency, they resemble analcime; they are somewhat more lustrous, however, than the analcime here present, both on the surface of their planes and on the fracture.

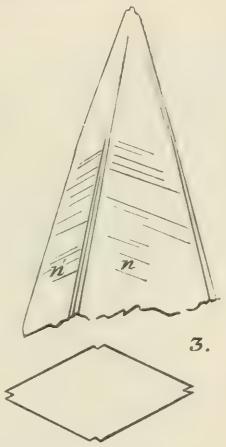
Their form I am only able to speak to from one or two minute crystals which were shaken off the specimen during carriage. That form is inexplicable.

At first sight they look like pseudomorphs after "dog tooth" calcite. Closer observation shows them to be acute four-sided pyramids. Such pyramids as might be formed by the two lower medial front-, and the corresponding lower medial back-faces of the summit half of an icositetrahedron.

The employment of a powerful lens discloses that, instead of this being merely a distorted crystal of analcime, —distorted through the two pairs of lateral faces of the icositetrahedron being reduced

to mere linear dimensions. a re-entering angle runs up the side, at the acute edge of the four-sided pyramid; and a re-entering angle of extreme minuteness also runs up at the obtuse angle.

A rough sketch is here given. The angle $n\ n'$ seems greater, if anything, than that of the icositetrahedron. These faces are faintly striated. There seems to be a second slightly more acute face surmounting n. The flash comes upon n of the back half of the twin, at the re-entering angle at the side, almost simultaneously with that from the front half (Fig. 3).



3.

In the *section* drawn, the size of the re-entering angles is much exaggerated.

The appearance is more that of inter-penetrating crystals than of true twins; indeed twins of such a description would be difficult to explain. These crystals were only seen upon one specimen. While there is no mineral more subject to distortion than analcime, such a distortion, or building together of crystals, would seem to defy explanation.

The summits are generally fractured. Occasionally a small crystal with the ordinary obtuse angles seems perched upon the summit of one of these marlinspike-like crystals.

The complexity of composition of analcime in no way *theoretically* entitles it to aspire to the perfect symmetry of the monometric system,—which would seem to pertain to a certain class of elements, and to binary compounds.

The microscope also discloses that it has a molecular structure which approaches in complexity to that of leucite, and that it must find its place among the *tesselites*.

The law of the arrangement of the diversely refracting parts is not in analcime *definite*, as in apophyllite, &c., and possibly the above strange form may aid in disclosing whether there is in its case any law.

Cavities of pre-existent baryte are seen in the specimens which carry the harmotome. I have elsewhere observed this, as well as in those specimens which carry edingtonite. Indeed I have speci-

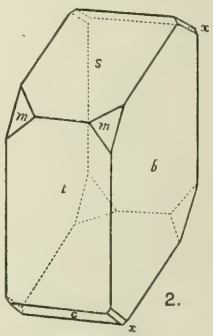
mens in which the baryte is only partly decomposed or removed. This seems to show that baryte was at least one of the substances which by decomposition yielded the two barytic zeolites.

But what has become of the sulphur *here*? In one of the previously observed cases, blende was present; in the other, galena and greenockite were associates. If this locality is opened up, some sulphide will probably be found.

Analcime in a massive form fills rents in this rock.

Crystals of laumontite, over 1 inch by $\frac{1}{4}$ of an inch in width, *underlie* analcime in some specimens.

One specimen carried white stilbite *a b r p*, cluthalite *n*, laumontite, chabasite *r*, and trihedral quartz.



Flesh-coloured lustrous natrolite occurs in fair specimens.

Red heulandite *per se* in small crystals *s t b m p x* (Fig. 2), occurs in small druses, being very rarely overlaid by brilliant colourless crystals, *s t b m p*.

There is one fine specimen of large sheafy red stilbite, with small, and with one large crystal of red heulandite.

The crystals of red heulandite are figured, to show the extreme difference in the development of their faces, although the localities are not four miles apart—although the containing rock is the same—and although the associates are the same, or much the same.

Whether we are to assign this difference of habit in the crystals to difference of size of the druses which contain them, or to difference of depth in the crust—entailing difference of pressure, my ignorance of the localities does not entitle me to suggest. Or whether it may be due to a difference in the rapidity of supply of solidifying material—labradorite having possibly been decomposed in one case, and anorthite in another. The time has certainly arrived when much fuller chronicles must be kept of the paragenesis of minerals—their *associates* in all cases—and, above all, the *sequential order* of their deposition in cavities.

Such chronicles we must have before we can hope to explain ever varying and extreme changes in crystalline habit;—and what is even more inexplicable—the association of extreme varieties in one and the same cavity.

There can be no question that if this locality were properly opened up, it would yield a rich harvest. Possibly similar works in the Campsie group may have supplied some of the older specimens; the heavy embanking at the Walton reservoir may have been the source of those assigned to Fintry. The three finds at this east end of the chain of hills show that once the eye is educated to accurate research in some one domain of science, it is capable of doing good work with little effort in another.

No. V.—On Some *Estheriæ* and *Estheria*-like Shells from the Carboniferous Shales of Western Scotland. By Professor T. Rupert Jones, F.R.S., F.G.S., *Honorary Member*. With a Plate [No. V.]

[Read 13th March, 1890.]

Some years ago my friend Mr. John Young, F.G.S., drew my attention to some *Estheria*-like shells from the neighbourhood of Glasgow, and one of them in particular seemed to me at the time to present features sufficiently characteristic to allow of its being referred to that genus of bivalved crustacea. Since then both Mr. Young and myself have examined it and its associates again and again; and I have come to the conclusion that its form is that of a *Posidonomya*, and that its punctate ornament can be matched among Molluscan shells. Hence it has to be removed from the Crustacean genus, and is treated of further on at page 83 as *Posidonomya punctatella*, Jones.

Among the Carboniferous specimens, however, that have come under our notice are other little *Estheria*-like fossils, and of these I offer the following descriptions, with figures very carefully executed by Mr. George West, who illustrated my "Monograph of Fossil *Estheriæ*," Palæontographical Society, 1863. The plate has been drawn with aid of a grant from the British Association for the illustration of Palæozoic Phyllopoda.

1. Estheria Youngii, *sp. nov.*
(Plate V., figs. 1*a*, 1*b*.)

This well-preserved right valve, retaining its outline and nearly full convexity, is sub-triangularly ovate, being straight above on the back or hinge-line, elliptically and obliquely curved below, obliquely rounded in front, and contracted and somewhat obliquely truncate behind. It is 8·5 mm. long, 4·5 mm. broad at its greatest height—that is below the umbo, and at one-fifth of the length of the valve from the extreme front margin and only 2·5 mm. high or broad at the posterior margin.

Below the umbo, which is bare, having been damaged, there are still present ten strong concentric ridges, with wide interspaces, curving neatly in front, and turned up sharply behind, all being parallel with the free (ventral and posterior) margins. The intercostal spaces are marked with obscure and very faint longitudinal striæ (not shown in the figures), also with a scarcely-distinguishable minute punctation, seemingly arranged at one spot in vertical rows. (Fig. 1*b*.) The inside of a similar valve shows numerous longitudinal striæ much more plainly.

The chitinous aspect of the valves, the sharp concentric ridges and their broad flat interspaces, even without the obscure punctation, are characteristic of an *Estheria*. Other specimens, less perfect, occur on the face of the small piece of shale; and some less definite fragments of valves on the other face, together with some valves more circular in shape, of about the same size, and punctate (fig. 7), formerly described as *Estheria punctatella*. All these are non-calcareous.

A very small *Anthracomya* (3 × 1 mm.) very similar in shape to *Naiadites angulatus*, Dawson ("Acadian Geology," 1878, pp. 204, 205, fig. 46), and calcareous, lies close to the figured specimen (fig. 1*a*).

This shale is from the Upper Limestone series of the Carboniferous Limestone, and lies below the limestone at the Arden limestone quarry near Thornliebank, four miles south-west of Glasgow. (See "Catalogue of the Western Scottish Fossils," &c., 1876, p. 91.)

2. Estheria tessellata, *sp. nov.*
(Plate V., figs. 2, 3, 4*a*, 4*b*.)

In the British Museum is a small slab of cannel-coal labelled

"Ayrshire (?)"* bearing a great number of small delicate valves (mostly double) of what seems to be an *Estheria*, lying close together on the surface. These are now represented by thin, light-brown, earthy, non-calcareous films.

In shape they vary much, apparently from the effects of pressure. The umbo is almost mid-dorsal, whether the valve has been elongated (fig. 4*a*) or not (fig. 2); the latter probably approximates more nearly to the normal shape, with the umbo rather forward, and the elliptically sub-oval valve measuring diagonally about 7 mm. in length, and about 4½ mm. high. The dorsal edge or hinge-line is about 4 mm. long in each case.

The numerous, exquisitely delicate, concentric striæ on the surface have between them minute quadrate pits, defined by short vertical lines joining the long striæ at regular intervals (fig. 4*b*), and thus forming a decussated and tesselated pattern. This has the effect of giving a slight radiate appearance to some parts of the valve under the microscope. There are also coarser radial lines, which have been produced by pressure on the originally convex valves.

Among the specimens there are to be seen some edge-views (like fig. 3) of the bivalved carapace filled with matrix, about 3½ mm. wide, and 6½ mm. high. This relative height (if the valves have not been disarranged by pressure) goes to show that fig. 2 does not give the full height of the valves of this species. The figures of *Anthracomya lævis*,† Dawson, have some resemblance to figs. 2 and 4, but the striation is too coarse, and the umbo too near to one end of the hinge-line.

With regard to the minute sculpturing of the surface, Dr. Goldenberg figures a somewhat similar ornament for his *Estheria limbata* ("Fauna Saræpontana fossilis," Heft 2, 1877, plate ii., figs. 12-14, p. 43), and still closer for his *E. rimosa* (*loc. cit.*, figs. 16-18). The dorsal line in our figures 2 and 4 is much too straight, however, for *E. rimosa*. Dr. Baird has figured an analogous ornament, but consisting of little round pits, closely limited by longitudinal and cross lines, in the lowest (newest) part of the edge of

* It is probably from the Upper Coal-measures of Ayrshire, and similar to a cannel in the Upper Coal-measures at Airdrie, Lanarkshire.

† Salter, *Quart. Journ. Geol. Soc.*, vol. xix., 1863, pp. 79-80, fig. 2; and Dawson, "Acadian Geology," Suppl., 1862, and 3rd ed., 1878, p. 204, fig. 44.

the valve of *E. Jonesii*, *Proc. Zool. Soc.*, 1862, plate xv., fig. 1*d*. The ornamentation, though microscopic, has suggested the specific name *tessellata*.

The ornament on *Chione Californiensis* and *Lucina Sowerbii* is somewhat of the same pattern.

3. Estheria tegulata, *sp. nov.*
(Plate V., figs. 5, 6*a*, 6*b*.)

Scattered on or near a bed-plane in a piece of cannel-coal in Mr. John Young's collection, and probably from the Upper Coal-measures at Airdrie, Lanarkshire,* are many delicate small valves of what appear to belong to *Estheria*. They occur as thin, light-brown, earthy, non-calcareous films, leaving a glossy black surface when removed.

Some are elongate and sub-oblong (fig. 6*a*); others are shorter and more triangular. The umbo in each case is (or has been) at the anterior angle, as indicated by the position of the concentric striæ, which are very thin and numerous. The dorsal line is straight and about 3 mm. long in fig. 5; in fig. 6*a* it is longer and not quite straight, but depressed (perhaps by pressure) in the middle.

These are smaller than the valves of *E. tessellata*, figs. 2-4); but, being magnified much more, they look larger on the plate. As with those valves it may be that pressure has altered the shapes by elongating some very much (figs. 4*a* and 6*a*), whilst others almost retain their original form (figs. 2 and 5). Besides the shape of these better-preserved valves, the relative position of the umbo is very distinctive of the two species; and the minute sculpturing of the surface (shown in figure 6*b*) is another and peculiar feature of difference. Here the striæ, raised lines, or concentric edges of the successive layers of the shell appear to be neatly notated with numerous parallel short incisions (as it were), leaving so many squarish, tile-like portions of each edge to overlap the next little concentric furrow between the striæ.† Hence the proposed appellation *tegulata* (tiled).

* "Catalogue of the Western Scottish Fossils," 1876, p. 65.

† A similar ornament is figured in Dawson's "Acadian Geology," 1878, p. 302, fig. 102*c*, as belonging to *Microdon Hardingi*, Dawson, a molluscan shell (1¼-inch long) allied to *Arca*, and characteristic of the upper part of the Lower Carboniferous Limestone at Windsor, Nova-Scotia.

This ornament is associated with, and indeed gives rise to, a delicate set of radial lines (under the microscope), distinct from the radiating cracks. Thinking that this radiate appearance was the same as that noted by Dr. E. Weiss in his genus *Estheriella*, I referred to the specimens under notice as belonging to this genus in the "Seventh Report to the British Association on the Phyllopoda of the Palæozoic Rocks," 1889. Since then Dr. Weiss has very kindly sent to me type-samples of his genus, and I find that the radii are of a quite different character, are fewer, and are confined to the newer part of the valve.

4. Posidonomya punctatella, Jones.

(Plate V., figs. 7*a*, 7*b*.)

Estheria punctatella, Jones. *Geol. Mag.*, vol. ii., 1865, p. 185.

Estheria punctatella, Jones. *Trans. Geol. Soc. Glasgow*,* vol. ii., part 1, 1867, p. 71, plate i., figs. 5 and 5*a*.

This little fossil was first noticed by Mr. John Young, F.G.S., who exhibited specimens to this Society in 1865. (See *The Geol. Magazine*, vol. ii., p. 185.) It was afterwards described and figured in the *Transactions*, *loc. cit.*, but the two figures were not perfectly true. It has now been re-figured in Plate V., figs. 7*a* and 7*b*, and accidental chipping and flaking may account for some of the alteration in its appearance.

As Mr. John Young has already pointed out, similar fossils occur in great profusion in the Carboniferous shales at several localities in the West of Scotland; particularly, for instance, at the Linn-Spout, Dalry, Ayrshire, as well as in some shale at the Arden quarry, near Thornliebank, not far from Glasgow, and about 20 miles from Dalry. This quarry has not been worked for more than twenty years, and specimens are consequently not now to be had. The little specimen, however, here figured, is very much smaller than the others referred to; and it is not calcareous, though thicker and more brittle than the *Estheria Youngii* which occurs with it in the same piece of shale.

The figured specimen measures only 8·3 × 5·5 mm.; but those referred to as occurring also as Thornliebank are 28 × 19 mm., and those from the Linn-Spout, Dalry, vary from 20 × 11 mm. to 32 × 22 mm. All these larger forms from Dalry are moderately

* A note by Mr. John Young, F.G.S., on the occurrence of the strata follows the description of the fossil.

thick, whitish, and calcareous; and the large specimens from Thornliebank, though thinner by pressure, and more or less coated with a pyritous film, are calcareous also.

Like figure 7*a* in general shape, all these larger specimens have also the delicate superficial reticulation and pitting, shown in figure 7*b*, over all the concentric wrinkles and furrows of the shell. In some cases this consists of pretty little lozenge-shaped areas close together; in others they are bound by polygonal meshes; and in some they appear to be round. This minute ornament is due most probably to a reticulate structure, which has become filled up and obscured by carbonate of lime. It is apparent only on the surface of the shell.

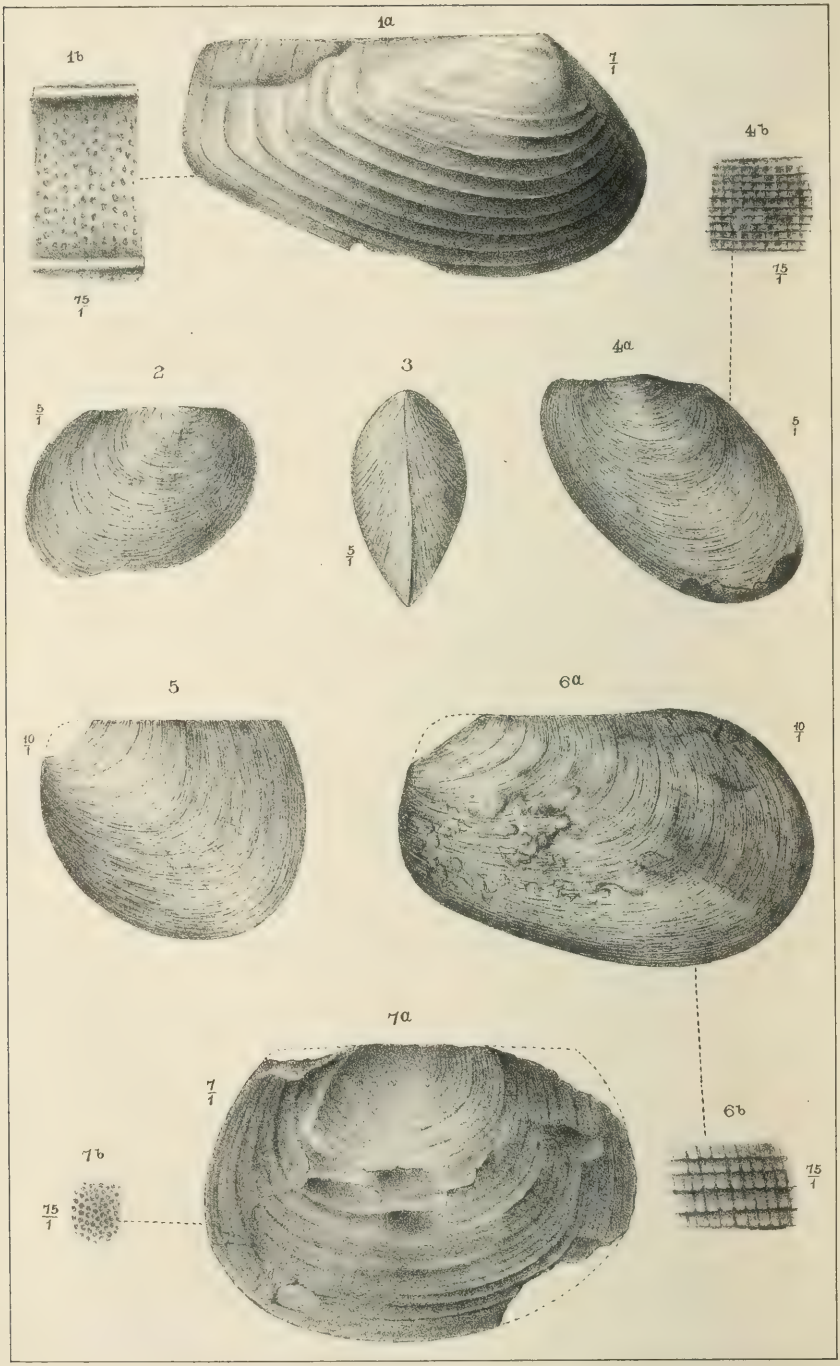
Excepting from its small size and its being non-calcareous, figure 7*a* may well be considered to belong to the same genus and species as the similar but larger forms above noticed. In that case it may be regarded as one of the younger individuals, and may have lost its calcic carbonate, remaining somewhat thick and brittle.

Hence I am induced to ignore my first determination (in 1865) of its relationship, and to relegate it to the Mollusca, more especially as a punctate ornament is not very rare among molluscan shells. *Lepton*, for instance, and *Kellia* have a delicate pitting or minute reticulation all over, not defined by concentric lines. Mr. John Young has noticed a somewhat similar reticulato-punctate surface on some well-preserved shells of *Posidonomya* and *Anthracoptera* of the Scottish Coal-measures, and also those of some other Carboniferous genera, as *Pinna*, *Aviculopecten*, *Pteronites*, *Myalina*, &c., sometimes associated with them.

The shales at Thornliebank and Dalry are on the same geological horizon, Mr. Young informs me, and are associated with the same group of organisms. They belong to the "Upper Carboniferous Limestone series."

The punctate bivalves under notice "exist in thousands, both at Darnley (Thornliebank), and the Linn-Spout (Dalry) in a thin shale, in which they seem to be the only organisms present;* but in the other shales lying close to it, above and below, we find examples of *Pteronites* and *Cypricardia*-like shells, having an estuarine or brackish character about them; and immediately below the lower shale is a seam of coal."—Mr. John Young, F.G.S., *in letter*, July 18, 1887.

* A Polyzoon and a small *Anthracomya* are noticeable as accompanying *Estheria Youngii*. (See above, p. 80.)



Geo. West & Sons del lith et imp

CARBONIFEROUS ESTHERIÆ &c., SCOTLAND.

Regarding these bivalves as molluscan, we may perhaps correctly refer them to Bronn's genus *Posidonomya*. This species may be defined as having broadly sub-ovate valves, when young almost equilateral, measuring from about 8·5 × 5·6 mm., with the hinge-line nearly straight, almost as long as the valve, and forming angles with the end margins; umbo in advance of the middle; anterior and ventral margins boldly curved: posterior curve rather less, being somewhat contracted below.

In the adult state the valves measure as much as 32 × 22 mm.; they are more nearly ovate than figure 7*a*; the hinge-line is straight, but is overhung by the umbo at about a third of the length of the valve from the front, and makes a more distinct angle with the posterior than with the front margin. The latter is rounder and fuller than the former; and an oblique ridge has left traces of its presence on the posterior moiety of some of the crushed shells from Dalry. The surface bears numerous concentric ridges or wrinkles, of unequal breadth, and with unequal intervening furrows. The whole is ornamented (when well preserved) with a microscopic reticulation; when perfect the meshes are slightly sunken, and the areas within them slightly convex; but varying from that condition to minute pits, and either lozenge-shaped, polygonal, or nearly round.

My friend Mr. Young has shown me clear evidence that the valves of *Posidonomya Becheri* exhibit the same punctate ornament, due probably to a prismatic structure of the shell, as is visible in the fossil valves from Thornliebank and Dalry. (See figure 7*b*.) The general appearance of these shells is also like that of some of the *Posidonomyæ*, and I have now little or no hesitation in referring them to this genus.

Explanation of the Plate.

Fig. 1.—*Estheria Youngii, sp. nov.* 1*a*, Right valve (×7 diam.); 1*b*, ornament (enlarged × 75 diam.) Arden quarry, Thornliebank; J. Young's collection.

Figs. 2, 3, 4.—*Estheria tessellata, sp. nov.* 2, Right valve, probably of almost the original shape; 3, edge view of a carapace full of matrix; 4*a*, right valve much elongated by pressure (all × 7 diam.); 4*b*, ornament (enlarged × 75 diam.) Cannel-coal, Ayrshire (?); British Museum.

Figs. 5, 6.—*Estheria tegulata, sp. nov.* 5, Left valve, probably of nearly the original size; 6*a*, left valve, elongated by pressure (both magnified 10 diam.); 6*b*, ornament (enlarged × 75 diam.); cannel-coal, Airdrie (?); J. Young's collection.

Fig. 7.—*Posidonomya punctatella*, Jones. Young state; 7a, left valve (× 7 diam.); 7*b*, punctate ornament (× 75 diam.). Arden quarry, Thornliebank; J. Young's collection.

No. VI.—On a Peculiar Structure—Spines within Spines—in Carboniferous Species of the Productidæ. By John Young, F.G.S., *V.P.*

[Read 30th May, 1889.]

The purposes for which the external tubular spines on the shells of the Productidæ existed have long been a source of conjecture to those palæontologists who have taken up this group for investigation, but in spite of all that has been written on the subject, we are still ignorant, in a great measure, as to what were their several functions.

As the spines are seen to be very variable, in the different species, both as to length, diameter, and numbers, it is probable that their uses may not have been the same in all cases, and future investigators may be able to show that some of the theories previously held may be correct only as regards certain forms.

In 1876, Mr. Robert Etheridge, jun., F.G.S., read a paper on an adherent form of *Productus* from the Lower Carboniferous Limestone strata of the East of Scotland (*Quart. Journ. Geol. Soc.*, p. 454), which was found attached, chiefly by its spines, to small stems of crinoids, polyzoa, &c. In describing his species—*Productus complectens*—Mr. Etheridge stated the opinions of those palæontologists who had expressed their views as to the functions of the spines, and tabulated their conclusions, as follows :—"The spines were considered—

1. "To be for the passage of tendons of attachment, by von Buch."

2. "To be for the introduction of water into the interior of the shell, by de Verneuil."

3. "To be for simply retaining the shell in position in fine sediment, by d'Orbigny."

4. "To be without essential functions, by Bronn."

5. "To be of unknown function, by Eichwald."

6. "Not to serve as means of attachment to the shell, by de Koninck and de Verneuil."

7. "Not to act as a conduit to the interior of the shell, by de Koninck and Bronn."

More recently, in 1880, our late Honorary Member, Dr. Thomas Davidson, in the Supplement to his "Monograph on the Carboniferous Fossil Brachiopoda," vol. iv., part iii., p. 305, Palæonto-

graphical Society, expressed his views as to the uses of the spines, and was inclined to consider their functions as having been somewhat varied, in the several species; and that they may be differently explained—some of the spines having been evidently used in some species for the purpose of attaching the shell to foreign bodies, while in others they may have helped to steady the shells on the soft muddy sea-bottoms on which they lived.

The discovery which I have now to record, the occurrence of spines within spines, and which forms the subject of the following remarks, appears to favour the view held by de Verneuil, that the tubular cavity of the spines in certain species served to admit water to the interior of the shell. This discovery, made quite recently, and quite accidentally, was unexpected on my part. I happened at the time to be grinding some sections of Carboniferous polyzoal shale, from Roscobie, Fifeshire, for examination under the microscope. In this shale there were some examples of *Productus scabriculus*, Martin, with the spines still attached and crushed down flat with the shell amongst the polyzoa. In some of the thin, transparent sections then made, several of the spines were cut through at various angles, and I found that near their attachment to the outer surface of the shell, and within the hollow tubes of the spines, many of the tubes were guarded by a barrier of minute spines, projecting inwards towards the centre in a radiating manner around the inner surface, and with their bases planted deeply within the wall of the spine. This I have endeavoured to show in the sketches and sections exhibited. These small spines are also seen, in the sections, to be tubular like those within which they are enclosed, and vary in numbers from a dozen to twenty or more. On the external, frontal surface of many specimens of the shell of *Productus scabriculus*, there are to be seen, in well-preserved examples, two groups of spines of different sizes, but, so far as I have examined them, the small internal spines, above referred to, appear to be present only within the larger spines. In the latter, which are about half a line in external diameter, the tubular cavity varies from one-third to one-half the diameter of the spine, and is now filled with an infiltration of structureless calcite quite distinct from that forming the spine walls themselves, these being formed of an organic calcite, having a dense and fine concentric lamination around the spines, and on their surfaces a silvery but slightly copper-coloured lustre, characteristic of nearly all the spines in the Productidæ.

When I first discovered this barrier of minute spines within the larger spines of *Productus scabriculus*, I thought the peculiarity might, perhaps, be confined to some single example, or to the beforementioned locality, but I have since found that it exists in all the specimens of the shell on which the spines are still attached, as well as in those from the strata of other localities within our Scottish coal-fields, although not always in the same fine state of preservation as those found at Roscobie.

In the numerous sections which I have prepared, I find that this peculiar arrangement of minute spines always occurs at the same point within the tubes of the larger spines, and is planted in what may be termed the neck of the spine just outside the surface of the shell, the rest of the tubular cavity outwards being free. In the sections one never sees the whole of the small spines which formed the barrier, as, generally, in both longitudinal, transverse, and oblique sections, more than half of the spines are cut away in the grinding before the section is thin enough to display them. These small spines are quite microscopic in size, and taper toward their points. Many of them project at nearly right angles into the tubular cavity, extending, in some instances, right across it. In other instances it is evident that numbers of them have suffered from erosion, their bases still remaining visible within the walls of the spine. This barrier does not seem to occupy a space within the length of the tubular cavity greater than the seeming diameter of the spine within which it is enclosed.

It will therefore be seen that, in preparing sections, it is only when the spines chance to be cut at the proper point that any traces of the barrier can be looked for. Hence in many cases, when examining sections which at first promise well under the microscope, it is found that most of the spines have been cut either too far away from the point where the barrier existed, or too close to their attachment to the surface of the shell; it is therefore only in chance sections that favourable examples turn up. Few sections ever show more than from twenty to thirty of the smaller spines present, but as they seem to have radiated inwards into the cavity of the spine all round its surface in an inosculating manner, at least double these numbers would probably be present in its perfect condition. Many of the barriers in certain of the species appear, however, to have had far fewer spines than is here noted.

The sketches which I now exhibit illustrate the appearance of

this barrier, and the number of small spines seen within those of the larger spines that have been cut in longitudinal, transverse, and oblique directions, according to the positions in which they chanced to lie in the shale. The sketches thus show how constant is its occurrence, and its position, in those spines in which it was present, and which have chanced to be cut at the proper points to show it.

Having thus shortly described the appearance of this arrangement of small spines, and its mode of occurrence, I shall not now offer any further opinion as to its functions, beyond what I have already stated, viz., that it seems to favour de Verneuil's view—that the tubular spines conveyed water to the interior of the shell, the barrier thus guarding the passage near the point where the tube entered the inside of the shell, and preventing the entrance of impurities, or minute organisms which might be enemies of the inhabitant. This view seems to be supported by the fact that only in the larger spines with the wider tubes is the barrier seen to exist. In all the species in which it is found the lesser spines appear to have had no barrier, because, probably, their tubular cavities were so small as not to necessitate the existence of such an arrangement, although still wide enough to admit the passage of water.

Since the period when I first discovered the barrier in the spines of *Productus scabriculus*, I have searched for its existence in some of the other species of the same genus, and have lately found it to be present in the larger spines of *P. punctatus*, Martin; *P. longispinus*, Sow.; and *P. semireticulatus*, Martin; but as the spines on the two last-named are few in number compared with those on the former species, I have failed, as yet, in getting as good examples of the barrier as those obtained in *P. scabriculus*.

Probably this barrier existed in the spines of other species of the genus, but owing to the difficulty of finding specimens with the spines still attached to the shell, and lying in a suitable position for being sectioned, it may be difficult to prove its presence in every case. I hope, however, that other examples may yet be found, besides those here noted. So far we do not know much regarding the extreme length to which the spines extended in the several species of Productidæ. Dr. Davidson, in his work above referred to, has carefully figured all the British species of *Productus* which came under his notice as having the spines still attached to the shell, but none of his illustrations show the full

length which the spines attained, although some of them are seen to have been at least 5 inches long. The original specimens of these I now exhibit. As stated by Dr. Davidson, it is probable that some of them may have been much longer.

The explanation I would here offer, as to the barrier being always found close to the base of the spine, and never further up the tube, is founded on the supposition that it came into existence during the earliest growth of the spine, and therefore close to the shell, the further growth and extension of the spine being not from the base, but by additions to its outer extremity.

In bringing these remarks to a close, I hope that they will lead to a further examination of this new and interesting structure, and thus help to establish more clearly at least one of the supposed functions of these tubular spines, viz., the passage of water to the interior of the shell, a function which is further indicated by the openings of the spines, as pores, on the inner surface of many of the shells.*

* Illustrated in the Supplement to Dr. Davidson's "Carboniferous Brachiopoda," plate xxxvi., figs. 16 and 17.

No. VII.—The Geology of the Lugton Valley. By James S. M'Lennan.

[Read 13th December, 1888.]

The valley through which the Lugton water flows is situated in the northern part of Ayrshire, with a small portion of its upper end in Renfrewshire, and comprises parts of the parishes of Neilston, Beith, Dunlop, Stewarton, and Kilwinning. It runs S.W., and is 13 miles in length, with an average width of nearly 2 miles. To the E. lie the parallel valleys of the Glazart and the Annick, and on its W. those of the Dusk and the Garnock.

With the exception of a few patches of peat moss, the district is a rich agricultural one, long famous for the excellence of its dairy produce. It contains no towns, and except in the hamlets of Ouplawmoor, Lugton, Burnhouse, Auchentiber, and Toranyard, and the mining villages of Doura, Bensley, and Fergushill, the population is mostly confined to its numerous well-appointed farm steadings. The mansions of Caldwell, Montgreenan, and Eglinton Castle with their surrounding woods and policies give a pleasing variety to the landscape, which is otherwise generally plain and unadorned.

The lowest rock in the valley consists of beds belonging to the upper member of the trappean series which forms the highlands of Renfrewshire, and stretches across its confines into Ayr and Lanark. These are made up of a variety of bedded basalts, melaphyres, and porphyrites, with occasional bands and beds of fine tuff and coarse volcanic agglomerate. Sometimes sandstones, shales, and thin impure limestones are seen. When continuous they are fringed with a border of ash-like strata, upon which rest the lower members of the Carboniferous Limestone series, and which vary much in different localities. At Beith and Caldwell they consist of ashy grits, sandstones and shales, with conglomerates, and seem to have been derived from the tear and wear of the underlying traps and tuffs. Sometimes they contain interbedded tuffs and agglomerates, showing that the volcanic forces were repeatedly active during the formation of the overlying mass.

While these trappean rocks are supposed to underlie the entire basin, they come to the surface only in its N. portion, and for a distance of 4 miles occupy the surface of the valley, except that part covered by Lochlibo, and a patch occupied by the Lower

Limestone series. Farther down, in the parish of Dunlop, they form the surface of the E. slope for a farther distance of 3½ miles, occurring twice on the W. side near the farms of Brownhills and Sidehead, both in the parish of Beith. In this first-mentioned locality these porphyrites contain augite and closely resemble dolerite.

On Lochridgehills farm, about a mile S.E. of Lugton station, a fine example of columnar basalt is seen cutting through the bedded felstone rocks—the columns being 5-sided, 6 to 10 feet in height, and 18 to 24 inches in diameter. "Many of them," says Mr. Dugald Bell, "are curiously curved, and the contraction joints between the columns, like those of Cathkin, are filled with vertical veins of calcite mixed with a green serpentinous earth. The basalt is a fine-grained rock, of a blackish-grey colour, and a friend informs us that on pounding it into fine grains he found some of it attracted to the magnet, showing the presence of magnetic iron ore in its composition."

Immediately over these trappean deposits lies the Carboniferous Limestone series, consisting of beds of limestone, shale, and sandstone, with seams of coal and clayband ironstone. A narrow tongue-shaped portion of this formation is situated in the bottom of the valley at its extreme N. end, some 16 acres of its extent being covered by Lochlibo. Near the E. side of this lakelet, beds of white sandstone have been quarried for building purposes, and old shafts are still to be seen where coal was wrought some forty years ago. Tradition says that the loch broke in and flooded one of these pits near its margin, several lives being lost. Half a mile W. of Caldwell house coal was wrought for several years in a pit near the march of the two counties, but being of inferior quality the work ceased about twelve years ago. A short distance below Caldwell station, and close to the railway, clayband ironstone is at present wrought, and at Lugton similar operations were carried on in a pit now filled up. On Waterland farm it is worked at no great depth in the method of early mining days by "ingaun ees."

In connection with this seam of ironstone is found a thin layer containing fine specimens of "Cone-in-cone" or "Maggie band," first figured and described by David Ure in his "History of Rutherglen and East Kilbride," 1793. In volume viii. of our *Transactions* a paper on "Cone-in-cone," by Mr. John Young, F.G.S.,

with illustrations of specimens from this very layer, gives the most satisfactory explanation of this peculiar structure yet put forward.

The limestone is found along the E. side of the valley for a mile below Lugton station, and, with the exception of the two faults caused by the trap already referred to, it covers the entire W. side for five miles. In two narrow strips at Bentfauld and Clonbeith it crosses the valley still farther down.

At Burock, about a mile N. from Dunlop, a "little outlying basin of the limestone entirely surrounded by the underlying igneous masses" is well seen in a railway cutting. Another detached patch occurs farther E. in the valley of the Annick at Gabrochill. The existence of such remnants shows that the limestone series once covered all this region, and that it was afterwards removed by denudation.

The limestone at Waterland is the main or lower limestone of Beith and Howrat. It is not so well developed in this basin as farther to the W., where it reaches a thickness of 100 feet—its highest development in Ayrshire, or indeed in Scotland. It is of considerable thickness, some 10 or 12 feet, and is intersected by joints or fissures perpendicular to the lines of bedding, which cause the rock to break up into large tabular masses. Its upper surface here presents a brownish appearance caused by a thin layer of volcanic ash, mixed with limey matter, said to overlie a large extent of the limestones in North Ayrshire. It contains numerous species of shells and corals, and remains of fishes, such as teeth, spines, &c., of *Psammodus*, *Helodus*, and *Petalodus*: and *Sigillaria* roots are frequently met with in its upper portion.

About three miles S.W. of Waterland, on Lugtonridge farm, the rock consists of a bed of whitish clay topped by a seam of coal 1 foot, 1½ foot of clayey shales, a post of limestone 3 feet, 1 foot of shale, 5 feet of dark-coloured limestone, nearly 3 feet of drab-coloured shales, surmounted by 1½ feet of vegetable soil.

Of the five limestones which the Survey gives as found in the Dalry basin, the lowest or Howrat limestone has the most extensive area. The Highfield limestone, the next in ascending order, can be seen, says Mr. Robert Craig, "in the Caldwell coal-field, and it crops out on the N.E. of Lochlibo, near Shilford, in the parish of Neilston, being found to the S. of the large fault which runs from Ardrossan up the Dusk and Lugton valleys into Renfrewshire.

Crossing into Kilwinning it stretches S.E. by Golderaig, Lyleston, and Clonbeith into the S. of Stewarton parish. It has been extensively wrought in all these places, and is still being mined at Moscow and Cessnock. Some doubts have been expressed as to the limestone of these last-mentioned places being the Highfield bed; but as it is on the same horizon and bears the same physical and fossiliferous characters as the Dalry deposits, it may be regarded as the same until it is proved to be different."

The two highest beds of limestone of the Dalry basin—the lower and upper Linn limestones—extend into the north of Kilwinning parish, and are seen on the Lugton water near the volcanic rocks found there, but much reduced in thickness.

The lower limestone is very rich in fossils, but while the Highfield beds contain few, the shales associated with them are very fossiliferous, and the Linn limestones contain many organic remains. The Survey gives a list of 96 fossils found in the Howrat limestone, and Mr. Craig, in the list attached to his paper "On the Upper Limestones of North Ayrshire,"* gives 96 as found in the Highfield, and 208 in the Linn limestones.

These consist of corals, crinoids, crustaceans, polyzoa, brachiopods, &c., up to fishes, and in the Memoir belonging to the 22nd sheet of the Survey, 77 genera or 182 species are named as being found in the coal basins of North Ayrshire. A good list of the fossils found in the Dalry basin is given by Mr. Robert Craig in vol. iii., part 2, of our *Transactions*.

Of the sandstones and shales included in the upper limestone series several fine sections are exposed on the banks of the Lugton near Montgreenan, where some of the higher members of the sandstone of a soft texture have been used for the manufacture of whetstones.

Above the Carboniferous limestone series, and separating it from the Coal Measures, there is found, in the S.W. of the Dalry basin, a large extent of later erupted volcanic rocks, well developed at Blair and Bankhead, where they form a ridge for some four miles with an average breadth of nearly half a mile. This great sheet of basaltic rock is also met with in the Lugton valley, beginning near Sevenacres Mill, and extending in a narrow strip past Montgreenan House, Old Mains, and Auchenharvie. In the last-named locality it forms the foundation on which the old castle of

* *Transactions*, vol. viii., part 1.

Auchenharvie stands, besides supplying the materials of which its outer walls are mostly composed.

The rest of the area of this basin is overspread by the Upper Coal Measures, with a breadth of two miles on the W. side, widening out to double that distance, and four on its E. border, being a small portion of the coal-field of North Ayrshire which stretches E. from Saltcoats by Kilwinning, Dreghorn, Kilmarnock, and Hurlford to Galston and Newmilns.

A little below Sevenacres Mill the main coal is seen cropping out on the banks of the Lugton, beautifully columnar by intrusive dolerite. It has the largest area in the district, and is the lowest at present wrought. It is of good quality and 4½ feet in thickness. A tradition runs that it has been worked for two hundred years. Mr. Rodger, the manager at Fergushill, informs me that there is an old pit on the side of the Lugton where the Kilwinning road crosses, and, when some of its old workings were gone through, the workmen found tools and wooden picks shod with iron lying as if left in a hurry, leading to the conclusion that the pit had been drowned out. This is said to have been one of the first pits in Scotland which had a pumping machine driven by water power, the pumps being made of wood hooped with iron. Traces of the dam with the "lade" can still be seen.

About 2½ fathoms above this main seam occurs a coal of very limited extent, from 1 to 3 feet thick. Some 2½ fathoms above this lies the Stone coal, which consists of 6 inches of coal, 10 inches of stone, and 22 inches of bottom coal. This is succeeded about 9 fathoms higher by the Eli coal 2 feet 8 inches thick, with a fireclay pavement. Then 3 fathoms up is found a coal of 1 foot thick, supposed to be the equivalent of the Blackband ironstone of Plan, near Kilmaurs.

The Ladyha' coal, with a thickness of 1½ feet, is met with 5 fathoms higher; and this is the seam chiefly wrought at Doura, supplying the fireclay manufactured there. A seam of oil shale 12 inches thick occurs 4 fathoms above this, and has 12 inches of coal underlying it. A ton of this shale, which contains the remains of fish bones, teeth, and scales, yields from 32 to 36 gallons of crude oil. It has been mined at Doura and is now worked at Annick Lodge.

Some 18 fathoms higher the Wee coal is found 2 feet thick, and 2½ fathoms above this another coal seam, known as the Turf coal,

3 feet thick, is met with. Above the Turf coal 2½ fathoms lies the Splint or Parrot coal, 3 feet 7 inches thick. The last or highest seam presently wrought at Fergushill is the Five Quarter coal, which is 4½ feet thick and of very limited extent.

Thus there are found in this basin of the Lugton valley no less than 9 seams of coal, with an aggregate thickness of 25 feet 7 inches.

In various parts of this river basin intrusive rocks of post-Carboniferous age are met with. These are supposed to be connected with the doleritic plateaux of Antrim and the Western Isles, of which the Giant's Causeway and Fingal's Cave are well-known portions, and are probably of Miocene age. These intrusives occur in the form of irregular bosses or sheets, and as dykes or veins. A little below Lugton station one of these dykes about 20 feet in breadth crosses the bed of the stream in a W. direction, forming a waterfall of about 5 feet high. Two miles farther south another dyke 60 feet broad strikes N.W. from near the village of Burnhouse through the Barr coal-field to the farm of Craighouse, some half mile S.E. of Beith. Its entire length is 3 miles. Along its N. side it is clearly defined, being in some places high and steep.

Near its end it rises 100 feet above the ground to the N., and at this point stands the castle of Giffen—a tower once 40 feet square, and five storeys high. The greater portion of it fell in 1838, and now only a small fragment of one of its corners remains. It belonged, with the surrounding barony, to a younger branch of the Eglinton family. When visiting this crumbling castle many years ago I noticed that it is in a straight line with Auchenharvie Castle, already referred to, and with Dundonald Castle in Kyle. This last, once a royal residence, and the scene of the death of Robert II., is built on a boss of the very same rock on which Giffen stands.

It is an interesting fact that from very early times such elevated masses of intrusive rock have been selected as sites for strongholds, and that, in Scotland at least, most of our great historic castles have been so placed. Those of Edinburgh, Stirling, Dumbarton, and Dunbar all occupy the summits of commanding heights of this rock, around which the din and strife of human passion have often raged.

I am reminded in this connection of a striking passage in Hugh

Miller's "Geology of the Bass," wherein he says, "I remember at one time deeming it not a little curious that the early geological history of a country should often seem typical of its subsequent civil history. If a country's geological history had been much disturbed; if the trap rock had broken out from below, and tilted up its strata in a thousand abrupt angles, steep precipices, and yawning chasms, I found the chances as ten to one that there succeeded, when man came upon the scene, a history, scarcely less disturbed, of fierce wars, protracted sieges, and desperate battles. The stormy morning during which merely the angry elements had contended I found succeeded, in almost every instance, by a stormy day maddened by the turmoil of human passion."

Some 3 miles further S., near Auchentiber, there occurs on both sides of the Lugton a ridge of volcanic rock nearly 2 miles in length, which differs from the two last-mentioned in running slightly N.E. For some distance it is parallel to the Lugton, and at its N. end it rises on its W. side some 30 feet above the stream. Hard and compact in some places, in others it is soft, weathering into a dark brown earth which forms an excellent soil. Several of these intrusive dykes are met with in the Fergushill coal-field—the largest stretching in a direction similar to the last.

The Drift series found in this district comprises the Boulder-clays, sands, and gravels forming the Kame series of the Survey. The Boulder-clay covers a large extent, and the lower division is of varying thickness, tough and compact, and, where it overlies the Coal Measures, is of a dark gray or bluish colour. It is full of stones small in size, more or less rounded and well striated, which are mostly of local origin. The underlying rocks are smoothed and striated, as is specially evident over the limestone surfaces, and the striæ show a direction nearly N. and S. I am not aware of any arctic shells or mammalian remains being found in this area, as was the case in the Carmel valley near Kilmaurs, and in Cowden glen a little beyond the N. water-shed of the Lugton. The upper portion of the Boulder-clay is coarser in quality, and not so dense in texture as the lower, and often contains large angular stones. As the district is an agricultural one most of the erratic blocks which once studded its surface have been removed. About half a mile beyond the E. water-shed of the basin, on the farm of Brannelside, in the parish of Dunlop, one of these blocks is still to be found. It is known as "The Thougrit Stane," and is a mass of

blue augitic porphyry of hard and compact texture. It is oval in form, rises to a ridge-like shape on the top, and measures 12 feet 6 inches long, 4 feet 6 inches above the ground, and 8 feet at its greatest breadth; it probably contains upwards of 800 cubic feet. Some have thought that it was once a Loganstone or rocking stone.

A short distance N.E., at the base of a steep cliff of trap, stood a small chapel, now entirely removed, which was dedicated to the Virgin Mary, and there is a popular tradition that for sins of a certain carnal nature the transgressors had to do penance at "The Thougrit Stane" by going round it on their bare knees so many times each day according to the nature of the offence.

The Boulder-clay lying immediately below the vegetable soil contains, in many places, the remains of the roots of trees, mostly oaks, showing that a thick forest once covered most of this region; and the small number of places in its area bearing Celtic names shows that its population must have been sparse when Gaelic was spoken in S.W. Scotland.

The only deposit of Sand and Gravel I know of in this locality is a little to the N. of Lochlibo; it is circular in form and of small extent.

At either end of this loch small patches of Alluvium have been formed by gradual silting up from materials washed down from the higher grounds, and from the decay of water plants. The Caldwell meadows have had a similar origin, and before the Lugton deepened its channel near Bentfauld a lakelet of more than a mile in length stretched N. from that place. Its site is now fine alluvial land, and the bed of the stream running through it is overgrown with *Equisetæ*—the last remains of the aquatic vegetation. The level lands near the confluence of the Lugton and Garnock Waters, now forming part of the pleasure grounds of Eglinton Castle, are composed of materials washed down by these streams, and to this circumstance their level beauty and high fertility are largely due.

The last formation to be noted in this district is the accumulation of vegetable matter known as Peat Moss, which is found in detached patches, generally in basin-shaped hollows of varying extent. There are six such areas—Bloak, Dykehead, Auchentiber, Cockenhead, Sidehead, and White Mosses—the first named and largest containing 640 acres. A considerable area around the margins of these patches, where the moss is of little depth, has

been brought under cultivation. Some forty years ago large quantities of peat for fuel used to be dug from all these mosses, but at present, owing to the cheapness and easy carriage of coal, the "casting" of peats has nearly been discontinued.

Trunks and roots of oak, willow, birch, and hazel trees are found in the mosses. The oaks seem to have mostly grown on the outskirts of the basins, and, judging from the remains of roots and trunks, must sometimes have been of a great size. But the stems of trees found are very few in proportion to the roots, and it has been thought that the former may have been largely removed by human agency.

Hazel nuts are often found imbedded among the twigs and branches on which they grew.

The Minutes of the Society of Antiquaries, for 17th Nov., 1791, refer to an interesting discovery made in Cockenhead Moss—"Dr. Ferris presented to the Society a shield dug out of a large moss about 1779, 6 or 7 feet below the surface, when the people who found it were casting peats on a farm called Lugtonridge, near Giffen Castle, in the parish of Beith. There were four or five more dug out at the same time, and they were observed to have been regularly placed in a ring. The possessor of the estate, Bailie John Storie of Paisley, could only procure this one, as the labourers had destroyed the rest before he had received any information of the discovery of them. It is of brass, $26\frac{1}{4}$ inches in diameter, embossed in the middle, and hollow on the other side to admit the grasp of the hand." Similar bronze bucklers have, I understand, been found at Yetholm on the Border. Probably a shallow lake once occupied the centre of this area, with a broad strip round it clad with a thick growth of birch, hazel, and willow, and that bordered by a dense forest of goodly oaks. Possibly under this forest shade those bronze bucklers were laid down around the grave of one of the tribal chiefs. Club mosses and water mosses grew, and died, their decay forming soil for their successors, the deposit spreading in extent and increasing in thickness until the lake was overspread, the brushwood overhid, the shields overgrown, and the fallen oaks buried out of sight, the peat moss we now see covering all in its dark embrace.

No. VIII.—Phenomena of the Glacial Epoch: II. The "Great Submergence." By Dugald Bell, *V.P.*

[Read 9th May, 1889.]

Introduction.—The *Reports* of the Boulder Committee of the Royal Society of Edinburgh, which were recently completed, furnished some matters for consideration in a previous paper* with regard to the position of these travelled blocks, and the theory assigned in the *Reports* for their transport, viz., by means of floating ice or bergs. We endeavoured to show that the facts recorded as to the positions of the boulders and their lines of dispersal point rather to the agency of a great sheet of land ice. We wish now to consider an essential part of the iceberg theory when applied to account for these boulders, viz., a great submergence of the land. In one of the *Reports* referred to it is stated that, if the phenomena under discussion be due to icebergs, a submergence of some 3000 feet is thereby implied; but in this, it is added, there is nothing improbable. Few, however, will adopt this extreme view. Those who think a considerable submergence is required to account for the phenomena usually contend for one of not more than 1500 to 2000 feet.

The succession of events during the glacial epoch is generally set down thus:—

1. A period of *extreme glacial conditions*, when the country was deeply buried under land ice, like Greenland at the present day.

2. A period of gradual *submergence* to the depth in some parts of 1500, in others of 2000 feet, with glaciers still existing in the groups of islands which then formed all of the country that was visible.

3. A period of gradual *re-emergence*, during which the marine drifts formed during the second period were ploughed out of the valleys by a *second* set of glaciers, in some localities of considerable size, but smaller than those of the first period.†

Some geologists are disposed to advocate several other minor "oscillations of level" during the glacial epoch. But there seems to be a general agreement, among many of them at least, with regard to the principal submergence, *i.e.*, of the second of these

* See *Transactions*, vol. viii., part 2, p. 237.

† See *e.g.*, Ramsay's "Physical Geology and Geography of Great Britain," chap. x.; and Lyell's "Antiquity of Man," chap. xiii.

periods, which is held to have divided the glaciation of the country into two distinct stages, and which is usually styled, as an understood and established point, "the great submergence."

Our Object.—The position we venture to take up in the present paper is, that this "great submergence" is very far from being proved. In several respects evidence is either wholly awanting or quite inconclusive: in none is it such as to put the matter beyond reasonable doubt. There is, indeed, good proof of *some* submergence during part of the glacial epoch, say of a *few hundred* feet—from three or four to five or six hundred perhaps (its limits have not yet been well defined over the country generally)—but anything more than this, or at all approaching 2000 feet, not to mention higher figures, has *not* been established, and we think, can be shown, on a review of the facts, to be extremely doubtful or open to question.

It may be a good exercise for us, then, as students of the science, to examine, with all respect for the writers who adduce them, but as thoroughly as we can, and as all true teachers in geology would wish us to do, the facts usually brought forward in support of this "great submergence."

Imperfection of the Evidence.—The first point that strikes us is the *defective* nature of the evidence on which this alleged "great submergence" rests. There are, to begin with, no distinct or traceable old coast-lines at all approaching to such a height; whether cliffs with their sea-worn caves, or shelving shores with their zones of beach pebbles, or receding bays of beds of gravel, sand, and silt, mixed with marine fossils. Nothing of the sort. The entire absence all over the country of such indications of the former presence of the sea at such high levels—assuming that it ever stood there—is remarkable. The late Dr. Robert Chambers, it is true, in his interesting book on "Ancient Sea Margins," gave a number of instances of what he took to be old sea-beaches at various heights approaching, or even exceeding, 1000 feet. But it is now generally admitted that this esteemed writer was quite mistaken in regard to those so-called high-level beaches. They are not really sea-beaches. Some of them are simply lines of weathering, where the strata are horizontal or nearly so; others are flutings formed by the action of glaciers; others are river deposits: and others again are the margins of ancient lakes.*

* See Geikie's "Great Ice Age," p. 297.

We may say, then, that so far as beaches, or coast-lines, or undoubted marine drifts are concerned, there are absolutely no indications of anything like the great submergence contended for. And, as we shall see later on, the entire absence of these, on the supposition that such submergence really took place, is not satisfactorily accounted for by any theory that has yet been broached for the purpose.

Further. Points have been brought forward as evidences of submergence which are not really so. Sir Charles Lyell, for example, generally so clear and careful in his statements, speaks of its being inferred "from the joint evidence of marine shells, erratics, glacial striæ, and stratified drift at great heights, that Scotland was, during part of the glacial period, 2000 feet below its present level, and other parts of the British Isles 1300 feet."* It seems wonderful that Sir Charles could enumerate such particulars together and class them as "joint evidence," some of them being clearly very imperfect evidence, and others none at all, of the former presence of the sea.

Erratics and Striæ.—Erratics and glacial striæ, for example, are at least as probably the effects of land ice, nay, far more probably—for no floating ice could produce the regular continuous striæ found everywhere diverging from the main mountain chains, or cause the mingling of nearer and more distant kinds of rocks among the erratics, or leave these travelled blocks in the positions in which many of them are now found.† The confusion in Sir Charles's statement may be illustrated by saying that the kind of evidence for placing Scotland 2000 feet beneath its present level would, if held valid, depress other parts of the British Isles quite as much; and on the other hand, the kind of evidence that would restrict the submergence in those other parts to 1300 feet, would restrict it in Scotland to a little over 500 feet! Besides, if we are to conclude the former presence of the sea from such marks as "erratics and glacial striæ," we have them in Norway and North America from 3000 up to 5000 or even 6000 feet; and the question arises, where and upon what principle are we to draw the line up to which they are to be taken as proving marine action, but not beyond?

Shell-less Drift.—"Erratics and glacial striæ" must therefore be dismissed entirely as evidences of the former presence of the

* "Antiquity of Man," p. 274.

† See Author's previous paper, *Transactions*, vol. viii., p. 247.

sea. Nor can we infer marine action more confidently from "stratified (unfossiliferous) drift," for this may have been produced by glacial action, or rivers, or lakes. Some of these deposits of roughly stratified unfossiliferous sands and gravels at high levels, which were at one time assigned to marine agency, have since been shown to be either moraine matter partially re-arranged by streams, or to have been deposited in local accumulations of water caused by the blocking up of the usual drainage during part of the glacial period.* In short, we may say of all these high-level gravels without shells, there is no certainty about them; they are utterly worthless as evidence without shells. "Professor Ramsay," we are told, "estimated the probable amount of submergence during some part of the glacial period at about 2300 feet; for he was unable to distinguish the superficial sands and gravel which reached that high elevation from the drift which, at Moel Tryfaen and at lower points, contains shells of living species."† We yield to none in admiration of Professor (now Sir Andrew) Ramsay, whose influence among geologists all over the world is deservedly high; but his own writings teach us how perilous it is to conclude the marine origin of sands and gravels from general appearance, or from resemblance to other deposits. At the time when he wrote his most interesting little work on "The Old Glaciers of Switzerland and Wales," the Professor was a thorough adherent of the iceberg theory; he believed that "Switzerland also lay beneath the sea *at least* 2000 feet beneath its present level;" that the huge blocks of Monthey, in the Rhone valley, had been transported by floating ice; and that "icebergs derived from Alpine glaciers" floated blocks equally huge to the Jura mountains. In support of this conclusion, he stated that the erratic blocks on the Jura "rest *on and in* stratified sands and gravels;" and with regard to those at Monthey, he wrote:—"Where the blocks do not rest directly on the shale that forms the hill, *they lie on and in* a sandy gravel roughly stratified, the material of which consists of fragments of granite, gneiss, limestone, and sandstone, generally well water-worn, a large proportion of the pebbles being quite rounded by abrasion like pebbles on the shore." This débris he goes on to describe as "being less angular than much of the drift of the midland counties,

* T. F. Jamieson, *Quar. Journ. Geol. Soc.*, vol. xvi.

† Lyell's "Student's Manual," 1871, p. 158.

Anglesey, or some of the Carnarvonshire beds with marine shells. "Like these too," he adds, "it bore to my eye the signs of aqueous deposition."* Now we suppose there is not a geologist in Europe who holds that Switzerland was submerged during any part of the glacial epoch, or has the least doubt that the transportation of erratics in that country was due solely to glaciers and not to floating ice. A good many years before Sir Andrew published these sentences this had been clearly established by the Swiss geologists, from the distribution of the erratics, their arrangement in distinct areas according to the valleys, and even the *side* of the valleys to which they belonged, and other particulars. In 1863, Sir Charles Lyell, after visiting Switzerland and going over the evidence, formally withdrew his previously expressed view as to the action of floating ice in that country, and agreed with the conclusions of the Swiss geologists.† Nay, some years later, these conclusions were adopted by Sir Andrew himself as regards Switzerland, though he still, in 1872, wrote of "the sea having risen at least 2000 feet on the Welsh mountains."‡ We have entered into these particulars, not for the purpose of proving that Sir Andrew Ramsay made a mistake, which is a small matter, but for the purpose of showing how impossible it is for even the most experienced geologist, in the absence of organic remains, to assert with confidence that certain sands and gravels are marine. As Dr. James Geikie has remarked, "When we consider the conditions under which the great glaciers disappeared, we cannot but be chary of ascribing any deposits met with in the interior of the country to the action of the sea. Beds of gravel, sand, and silt occur in such extraordinary positions in the Alps and other highly-glaciated regions, that we may well pause before deciding on the marine origin of any such unfossiliferous deposits occupying similar positions in our own country."§

We submit, then, that the whole of the high-level gravels without shells are thus swept out of the reckoning. The testimony we have adduced proves that they may have had another origin than the action of the sea.

* "Old Glaciers of Switzerland and Wales," 1860, pp. 31-33.

† "Antiquity of Man," p. 247.

‡ "Physical Geology and Geography of Great Britain," 3rd ed., pp. 144 and 154.

§ "Great Ice Age," p. 297.

Shelly Sands.—The only remaining piece of evidence we have to fall back upon are the sands containing marine shells. Of course where these are found to all appearance *as they were left by the sea* there is good evidence, and as far as we have gone, it seems the *only* good evidence, of a former sea-level. Let us see, then, how far this evidence will carry us.

Their General Height.—Scotland.—In Scotland, the highest point at which marine shells have been discovered is, we all know, at Chapelhall, near Airdrie, 510 feet above the sea. They have been found at Gamrie in Banff, at 350 feet; in Caithness and Aberdeenshire, at 250 feet; near Bothwell, at 200 feet; in other parts of the Clyde valley and elsewhere, at various lower levels down to the 40 feet beach. In these localities—none of them, it will be seen, at any great height—shells have been found of existing species, but implying a colder climate than that of the 25 feet terrace or the present sea. Assuming that the shells at Chapelhall were in place, which some doubt, for there seems to have been only a limited patch of the shelly clay, some two feet thick at most, imbedded in Boulder-clay, and it *may* have been transported; but giving this instance its full value as a genuine instance of the shells *in situ*, the result, so far as this kind of evidence goes, is that the greatest submergence of which we have proof in Scotland is a little over 500 feet, or, making allowance for the depth in which the shells may have been deposited, say between 500 and 600 feet.

England.—Now this corresponds very nearly with the great majority of instances known to occur in the British Islands, leaving out of view, for the moment, a few at higher levels, to which we shall immediately refer. Thus, Sir Chas. Lyell states:—"As to central England, or the country north of the Thames and Bristol Channel, marine shells of the glacial period sometimes reach as high as 600 or 700 feet."* Dr. Crosskey, in a recent paper on the "Glacial Geology of the Midlands," concludes that the subsidence of the Midlands during the glacial epoch could not have been less than 500 feet. He thinks it may have been more: but of this he is evidently doubtful.

Ireland.—With regard to Ireland, Prof. Jukes, writing in 1862, in the second edition of his excellent "Manual," mentions a number of localities where "fragments of sea-shells are found in

* "Antiquity of Man," 3rd ed., p. 274.

the limestone gravel up to heights of 500 or 600 feet," and adds, "they have not yet been discovered from any greater height."* Since then, as we shall see, some have been found at a greater height; but we are safe in saying the great majority of instances in the United Kingdom are within the limits of 500 or 600 feet.

Other Countries.—It is worthy of remark that all these instances correspond very closely with the extreme height at which similar shelly deposits are found in other countries in the northern hemisphere, in Scandinavia on the one hand, and North America on the other. "The greatest height at which shell-bearing beds have been obtained in Norway is 600 feet above the sea."† "In the New World, as in Scotland and England, marine shells have rarely been traced higher than 500 feet above the sea, and 700 seems to be the maximum to which they are known to ascend."‡ Again, "In Canada and the United States, as in Europe, the marine shells are generally confined to very moderate elevations above the sea (between 100 and 700 feet)."§ "In Canada," says Sir William Dawson, "the depression, on the evidence of shells, must have been at least 500 feet."‖

So far, then, there is a very general *consensus* of evidence in favour of a submergence of a great part of the northern hemisphere to the extent of some 500 or 600 feet. We may confidently assume that similar conditions, both as to glaciation and submergence, prevailed in neighbouring lands and over the northern hemisphere generally. This is surely more credible than that some detached and limited areas were deeply submerged and others not; that Scotland, for example, was more deeply submerged than Norway and North America on the one hand, and than Wales or Ireland on the other; or that Wales and Ireland were more deeply submerged than other neighbouring parts of the British Isles. These things may be possible, but they are certainly not probable. The more limited and local, and the more variable from one point to another, such changes of level are represented to have been (while unaccompanied by volcanic disturbance of the strata) they are the more unintelligible and incredible.

* "Manual of Geology," p. 675.
† Geikie, "Great Ice Age," p. 409.
‡ Lyell, "Antiquity of Man," p. 354.
§ Lyell, "Student's Manual," p. 159.
‖ "Acadian Geology," p. 68.

Unless, therefore, some clear and indubitable evidence appears to the contrary, it is most probable that the submergence of the British Isles during the glacial epoch corresponded very nearly with that indicated in other parts of the northern hemisphere. And this only carries us to, at the utmost, 600 or 700 feet.

Higher Instances.—We now come to those instances which have been held to establish a much greater submergence than this. There are a few localities in Wales and neighbouring parts of England and in Ireland in which marine shells have been found at higher elevations than we have yet mentioned—as high as from 1200 to 1400 feet. These we must now consider in some detail, as they are the instances chiefly or solely relied on in proof of the "great submergence."

There is a hill in North Wales overlooking the Menai Straits, whose name, Moel Tryfaen,* is well known all over the world in connection with this subject. Near the summit of this hill, in a bed of "drift" 1360 feet above the sea, marine shells of existing species have been found, indicating colder conditions than at present, though not the extreme arctic conditions indicated by other shell-beds in Britain. "Drift" of similar appearance, though without shells, is found in the neighbourhood to a height of 2300 feet, which Professor Ramsay, as we have seen, considered might indicate the extreme limit of submergence.†

Similar shelly gravels are found in the neighbourhood of Macclesfield, Cheshire, at a height of 1200 feet above the sea; and in Ireland also, in some places on the flanks of the Dublin and Wicklow mountains, at about 1300 feet.

Such, we may say, is the entire evidence on which the "great submergence" rests. Shelly gravels in a few places at about 1300 feet; gravels *without shells* up to 2300 feet; conclusion, a submergence of over 2000 feet! And this conclusion specially extended to Scotland, where, as we have seen, no shells are found over 510 feet!

The gravels without shells we have already set aside.

What these Instances prove.—If now the conclusion be stated

* Meaning "a round-topped hill of three summits."

† "Fortunately," says Sir C. Lyell, "the evidence of the sojourn of the Welsh mountains beneath the waters of the sea is not deficient, as in Scotland, in that complete demonstration which the presence of marine shells afford."—"Antiquity of Man," p. 269. Why "fortunately?" Does not this reveal a bias quite unusual with Sir Charles?

strictly according to the evidence producible, we may take it from Dr. Archibald Geikie:—"From the evidence of marine shells, Southern Scandinavia is believed to have sunk about 600 feet below the present level, and North Wales at least 1350 feet."* To which we may add, Scotland between 500 and 600 feet, and North America about the same.

So far then as any semblance of proof has gone, the alleged submergence of 2000 feet or more becomes reduced to one of, at the utmost, 1300 or 1400 feet.

But even this, in face of the facts we have stated, is difficult to accept. It is hard to believe that North Wales and part of Ireland were more deeply submerged than the other parts of the northern hemisphere to which we have referred. Did the submergence increase southwards? That is not maintained. On the contrary, there are good reasons for believing that it rather increased northwards.

Difficulty with regard to them.—In any case, the exceptional position of these few patches of shelly gravel seems to suggest caution in our inferences regarding them. If they were really laid down, as we find them, by the sea, should we not expect to find similar deposits at a corresponding elevation in many other localities? If the sea once stood at that height, there must have been innumerable sheltered bays and inlets, narrow fiords and broad channels, at a similar level all over the country, in which marine organic remains should be found as well as here. Can any explanation be given of their being restricted to a few spots in Wales and neighbourhood, and in the east of Ireland; also of none being found anywhere between these at 1300 or 1400 feet, and the next instance in Scotland at 510 feet?

Explanation suggested—A Later Glaciation.—This brings us to consider the manner in which the absence, over the country generally, of all such traces of the sea, is usually accounted for, viz., that they were all destroyed or cleared away by the "later glaciation." In fact this second or later glaciation seems called into operation chiefly to remove the traces of the supposed submergence. It is represented to have been a "partial" or "local" glaciation; but we think a little consideration will show that, in order to do what is required of it, it must have been nothing less than a "general glaciation" over again.

* "Text-Book of Geology," p. 297.

Explanation not satisfactory.—When we think of it, does it not seem very *unlikely* that all traces of this deep submergence (if it took place) should everywhere, with these few exceptions, be obliterated, especially by the slighter and more local glaciation which is alleged to have succeeded? It is surely unlikely that any well-marked coast-lines, for example, at various heights far inland, should be all smoothed down and effaced by this "later glaciation." Also, that all the high shell-beds which must have existed in many places should, with these two or three exceptions, be entirely cleared out and swept away by the same agency. It seems to be expecting *too much* of the glaciers—especially those smaller local glaciers which are supposed to have done the work—that they should "plough out of the valleys" all the "marine drift," or sediments of any kind, formed during the long period (as it must have been) of submergence, and "leave not a wreck behind." For, in the first place, it appears that ordinary-sized glaciers, at least, whatever may be their other effects, have but a limited power of sweeping out and pressing before them accumulations of débris. One instance that may be given is the Glacier de Miage, described by Forbes as actually divided into two, not by any fixed obstacle in the valley itself, but solely by its own moraines accumulating in front of it, and forming a mound which parts the ice with less resistance than would have been required to push the huge heap forward. Another is furnished by the Glacier des Bossons, which, instead of pushing its terminal moraine clear before it, levels itself upwards, so to speak, and rests upon it as on "a steep embankment projecting into the valley."* The well-known "striated pavements" in the Boulder-clay of our own country also show that the ice, instead of pushing the clay all before it, pressed it here and there into a compact mass, and moved on over it.

But, secondly, supposing the "ploughing out," so far as it went, were more thorough and complete vertically than we have reason to think it could be, it is impossible to believe it could be complete laterally or horizontally. There is this great difference between marine and glacial action, which renders it quite certain that no local glacier could make a "clean sweep" of the marine deposits. The sea has a most devious, sinuous coast-line—at any level it must always have had such a coast line—winding into every recess

* "Tour of Mont Blanc," pp. 27 and 3.

and angle, into every little side valley and sheltered nook of the country; whereas a glacier keeps as straight as possible to one main channel. It does not branch off into side openings, merely because they are openings, as the sea does; but rather holds on straight across them and disregards them. In these side valleys, thus blocked up, glacial lakes may be found, like the Marjelen See and others. It is therefore incredible that subsequent local glaciers could make a thorough clearance of the marine deposits formed during a period of submergence. The glaciers could not branch off or flow out into all the curves and bays and recesses that were occupied by the sea. Whatever their action might be so far as it extended, it is simply impossible that their *area* could coincide with that of the submergence.

In another respect the clearance could not be complete laterally, or, as we may express it, *longitudinally*. In any valley which the sea had occupied to a certain height, the old coast lines and shore deposits would extend at a *uniform level* at some height along the hillsides bounding the lower part of the valley, while towards the head of the valley these lines and deposits would approach nearer to the summit level. There, and for some distance down the valley, they might be cleared out by a glacier. But it is improbable in the last degree that they would be obliterated in the lower part of the valley. The sea makes a line of uniform level; the glacier's is a *descending* line. The latter would soon cross and run beneath the former, which would then remain intact.

When we consider all these circumstances, we may safely conclude that the total absence of such deposits in other parts of the country at similar high levels is proof that they *never were there;* in other words, is proof against the submergence (of even 1400 feet or thereby) referred to.

This conclusion is certainly confirmed by keeping in mind what we have already stated, that in other countries in the northern hemisphere the evidences of the former presence of the sea terminate at about the same level as our own, with the exception of these instances which we are now considering and showing to be doubtful. It is not asserted with regard to these countries that they may have had shell-beds up to 1300 or 1400 feet, but that subsequent glaciers, with a singular unanimity or uniformity, destroyed all traces of them down to 600 or 700 feet!

Ordinary Denudation. The same remark applies to another cause which is sometimes assigned for the disappearance of such high-level beds (assuming them to have existed), viz., the action of the ordinary weathering agencies, included under the term "sub-aërial denudation." "Fortunately," if we may use Sir Charles Lyell's expression, we have a test case on this point in the well-known Parallel Roads of Glen Roy. These remarkable lines or shelves on the hillsides of that region are now admitted to be the beaches of old lakes that were "ponded back" in that side glen by the ice in Glen Spean and Glen More during part of the glacial period, at 1144, 1062, and 850 feet successively, above the sea. Our view is that they indicate the gradual retreat of great ice-sheet towards the close of the period. But others hold that they belong to the "second glaciation," which succeeded the "great submergence." It is certainly clear that the sea has never touched these shelves, even the lowest of them, since they were formed. It is clear also—and this is our main point at present—that at the time of their formation the ice must have been in great force—more than 1000 feet thick in the main glen—and therefore the snowfall heavy and the climate severe. The conditions, accordingly, would be unfavourable for the preservation of the higher shelves—nay, the "denudation" which undoubtedly accompanied the passing away of the ice altogether, would be unfavourable for the preservation of any of them. Yet they *are* preserved quite distinctly to this day in one of the rainiest districts, where "sub-aërial denudation" is most active, in Britain. Can anyone doubt that if there had been within the same comparatively recent period sea-beaches and shell-beds at similar heights all over the country, these would be equally and even more perfectly preserved? The sea, it is obvious, makes a deeper and more distinct notch on the land than a lake.

Supposed traces of the Second Glaciation.—We may note here that the facts from which Professor Ramsay—on whose authority it chiefly rests—inferred a "second glaciation," which cleared out of the valleys the "marine drift" that had accumulated in them during the supposed submergence—were such as these:—the banks and terraces of drift which occur along the sides of many of the Welsh valleys, and apparently mark the level of the drift at one time *right across* these valleys. Between these terraces, there is a lower "narrow channel, through which the brook runs, *bare*

of drift and boulders," which the Professor took to mark the course of the smaller glacier which, subsequently to the submergence, *ploughed out a long narrow hollow in the drift.** But all this is very uncertain; for these "terraces" may be simply the successive lateral moraines of the diminishing glacier, including the débris which would be washed down the hillsides and lodged against them. This is the explanation given by that acute observer, Mr. Jamieson of Ellon, with regard to such terraces in many of the Scotch valleys. He remarks on the total absence of organic remains in them; also on the fact that, when carefully measured, they are found to be *not horizontal*, as they ought to be if sea-margins, but *sloping sea-wards*; further, that they occasionally contain large heavy boulders, and are associated with elongated mounds and confused hillocks of coarse gravel of morainic character. He adds, "that such terraces and mounds can be formed without the presence of the sea is very well shown by the similar deposits that occur in the valleys of the Pyrenees, the Himalayas, and other mountain chains in the interior of continents, where we have reason to believe no sea has ever entered since the glacial period."† And he gives the following illustration, showing how these terraces

Fig. 1.—Section of Valley with Glacier in retreat. *c*, Glacier; *a* and *b*, Gravelly Débris. [From *Quar. Jour. Geol. Soc.*, 1874.]

Fig. 2.—Section of Valley after disappearance of Glacier. *a* and *b*, Gravelly Débris. [From *Quar. Jour. Geol. Soc.*, 1874.]

and the hollow between were in all likelihood formed during the gradual retreat and disappearance of the glaciers.

* "Old Glaciers of Wales," p. 10 (italics, as before, are the Professor's own).
† "On the Last Stage of the Glacial Period," *Quar. Jour. Geol. Soc.*, 1874

We may accept this as the true explanation till some more distinct evidence be forthcoming that these high-level "terraces and drifts" are indeed marine.

The High-level Shelly Gravels.—We must now turn to consider more particularly these high-level shelly gravels of Moel Tryfaen, &c., to which we have referred. It is evident that the whole value, even of marine shells, as evidence of the former presence of the sea, depends on their being accompanied by good tokens that they are actually *in place*, or as deposited by the sea. For it is quite possible they may have been disturbed, and *lifted to a higher position* than their original bed. We have good proof that shells, like stones or anything else, can be taken from where they have been deposited, carried to considerable distances, and left ultimately in positions a good deal higher than their original place. This can be done by land ice, and so far as we know, by land ice alone. Not to detain the reader here, we give in an appendix some instances of boulders having been so carried (see p. 135). It is evident also from the striæ that the ice may be in such mass as to move straight on over and across ridges that lie in its way, and that when it does so it can carry boulders or anything else with it. If it passes over a former sea-bed, or along an old coast-line, it may take up and carry forward with it marine shells, and deposit them elsewhere, in a more or less fragmentary condition, possibly at a higher level than where it found them. The shelly Tills of Caithness, Holderness, Cromer, and Lancashire are cases in point: also that of the Endrick valley, in our own neighbourhood, described by Mr. R. L. Jack in a paper read to this Society,* as occurring from 100 up to 320 feet above the sea, and as having been most probably pushed up by a glacier from what is now the bed of Lochlomond.†

Keeping all this in mind, let us look at these Moel Tryfaen deposits and mark carefully what appearances they present. Not to rely on our own observations during a hurried visit to the

* *Transactions*, vol. v., page 2.

† "Mere fragments of marine shells in a glacial deposit do not prove submergence under the sea, for they may have been pushed up from the sea-floor by moving ice, as in the case of the shelly Till of the West of Scotland, Caithness, Holderness, and Cromer. How far this may have been the origin of the shelly Till found in high levels in Britain has still to be determined." A. Geikie, "Text Book," p. 897.

neighbourhood some years ago, let us take them as described by a number of far more competent observers, and inquire what they indicate as to their mode of formation.

Description of the Deposits.—1. Professor Edward Forbes remarked on the usual fragmentary condition of the shells in the beds of the north-west of England, and their tolerably even distribution through the drift. He was much puzzled to account for these features, and imagined they might be due to "the ploughing up of icebergs and the great rush of ocean currents." Speaking of the Moel Tryfaen shells he said—"I have lately examined them carefully with a view to see whether they indicate an ancient coast-line or beach, or an ancient sea-bottom. But they cannot be regarded as indicating either, being a confused mixture of fragments of species from all depths, both littoral and such as invariably live at a depth of many fathoms." Such "deep and shallow water species mingled," he adds, "could at no time have lived together, or been thrown up on one shore."*

2. Sir Charles Lyell, who seems, notwithstanding this explicit declaration of the highest authority on the subject, to have always regarded these shells as being in place, and as indisputable evidence of submergence, described the deposit in which they occur as a "stratified mass of incoherent sand and gravel" near the top of the hill. "In the lowest beds of the drift," he observed, "were large heavy boulders of far-transported rocks, glacially polished and scratched on more than one side. Underneath the whole we saw the edges of vertical slates exposed to view, which here, like the rocks in other parts of Wales both at greater and less elevations, exhibit beneath the drift unequivocal marks of prolonged glaciation."† In another place he wrote of the deposit as "for the most part in thin and irregular layers, and containing here and there fragments of shells, with a few entire ones. In the lower beds," he added, "were several large boulders of far-transported rocks, glacially polished and scratched on more than one side."‡

3. Professor Ramsay admitted that "much of this drift," in the upper division of which the shells are found, "though rudely

* "Memoirs, Geological Survey," vol. i., p. 384.
† "Student's Manual," 1871, p. 157.
‡ "Antiquity of Man," p. 526.

stratified, singularly resembles ordinary moraine matter in the appearance and quality of its mud, and the polish, approximate angularity, scratched surfaces, and sizes of its stones."*

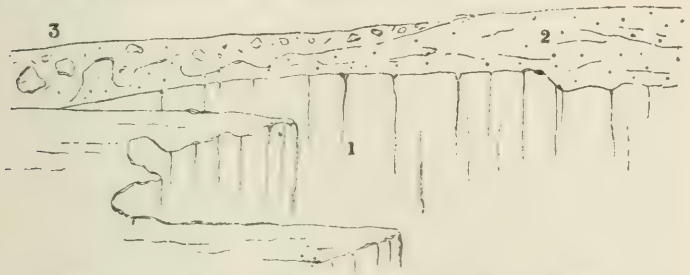


Fig. 3.—Section at Moel Tryfaen. 1, Cambrian Slate; 2, Shelly Sands and Gravels; 3, Glacier Boulder-clay. [From Ramsay, *Phys. Geol.*, p. 413.]

4. Dr. A. Geikie observes with regard to Moel Tryfaen that "the shells are broken and show such a curious commingling of species as to indicate that they are probably not really in place." And he gives other instances where fragments of shells occur in Boulder-clay, the ice-sheet apparently having "passed over some parts of the sea bottom, and ground up the shell banks that happened to lie in its way."†

5. Mr. Mellard Reade, writing on "The Drift Beds of the North-West of England," also remarks on the fragmentary condition of the shells, and the manner in which they are scattered throughout the drift. He notes that the shells most generally found whole are of a form best suited to resist pressure, and in some cases of quite minute dimensions. "Again," he adds, "the association of the various species distributed entirely without order through the clays show that they could not possibly have lived together on the same bottom, some being peculiar to sand, others to mud, some to rock, and others to shingle, some requiring deep water and others shallow; so that the conclusion is irresistibly forced upon us that they must have been to a large extent transported." The deposits vary considerably: "one part is more sandy or stony than another, one part contains gravel, and another consists almost wholly of a fine unctuous clay; but

* "Old Glaciers of N. Wales," p. 96.

† "Text Book," pp. 901-2.

throughout are the broken and rolled shell-fragments, and the scratched erratic pebbles and boulders." Mr. Reade accounts for the phenomena, however, by the action of tidal currents and coast ice during a period of submergence and re-elevation.

It appears from Mr. Reade's description that the whole of the *low*-level drifts* of Lancashire and Cheshire, occurring from about 50 up to about 175 feet above the sea, are a series of mixed, crushed, and transported deposits, which might be characterised as a *mashed-up sea-bottom*.

6. It is almost unnecessary to adduce further testimony, but we may also cite Mr. D. Mackintosh, who considered the Moel Tryfaen deposit was due to "floating ice." He describes the "irregularly stratified gravel and sand" as containing many boulders and pebbles "which may have been *worked up from their parent rocks on the N.W. side of the hill* by waves and coast ice as the land was sinking." [It is not easy to see how this could be.] He adds:—"A large percentage of the pebbles certainly, and some of the large boulders probably, were derived from the far north." Among these he enumerates "several kinds of granite from Cumberland and Scotland," among them "many pebbles and some good-sized stones of very decided Eskdale and Criffel granite. The latter (which must have travelled no less a distance than 130 miles) is generally of the same kind as the principal variety found in the drifts of Cumberland, Lancashire, and Cheshire, and is a perfect *facsimile* of granite now quarried at Craig-Nair, near Dalbeattie. The Eskdale granite embraces several varieties with which I was familiar on the E., W., and N. sides of Eskdale, and between the latter and Westwaterfoot." Fragments of these are also found in the Lancashire and Cheshire drifts. "These granites," continues Mr. Mackintosh, "must have been carried to near the top of Moel Tryfaen by rafts of coast ice [?] when the land was too deeply submerged to permit any granite falling on the surface of glaciers terminating in icebergs. Indeed," he adds, "there is some difficulty in seeing how even coast ice could have picked up granite from the Eskdale fells at a height of nearly 1400 feet above the present sea level."† We think so too; and have a further difficulty in seeing how, having picked

* *Quar. Jour. Geol. Soc.*, 1874.

† *Geol. Mag.*, 1872.

it up in Eskdale, coast ice could carry the granite to the shoulder of Moel Tryfaen. Would there not be coast ice there as well as here? How then, and by what skilful pilotage, could coast ice from Eskdale reach Moel Tryfaen?

Remarks.—Such being the appearances presented by the shells themselves and the gravels in which they are imbedded, we can hardly come to any other conclusion than the first part of that arrived at by Forbes many years ago, viz., that they "indicate the action of some disturbing influence—of having been accumulated far above the level of the then existing sea—through" *some* agency. Darwin suggested "icebergs:" Sir Roderick Murchison "waves of translation:" Forbes himself "the combined action of both causes:" Mr. Mackintosh, as we have seen, clung to coast ice; Mr. H. H. Howorth, a later writer on the subject, suggests a "great post-glacial flood," though it is plain that no such flood could transport pebbles and boulders a hundred miles or more, and that it must have left shells high along the sides of a hundred other channels and arms of the sea as well as here.

But indeed we may say, "'Tis past conjecture: all things rise in proof." There is every indication that these shell-beds on Moel Tryfaen are really a *glacial deposit*. The shells are fragmentary and mixed; the "drift" in which they occur is very unevenly bedded, and, Ramsay himself being witness, quite like the gravels of Switzerland. It contains, moreover, many far-travelled stones and striated boulders, mingled with pieces of rock from the immediate neighbourhood and *from lower positions on the hill itself;* and the rocks beneath are also striated. There is, in short, every evidence here of the former action of land ice, to which the formation of this "drift" is to be attributed.

This conclusion is so much in harmony with all the phenomena that we think there would be no hesitation in accepting it but for the *height* at which these shelly gravels are found. This seems to be the only difficulty; were they at the level of only a few hundred feet, this explanation would be accepted at once. Whether, after considering all the evidence there is of the former presence of ice at this point, and the evidence we have still to present of its having been in immense mass in the immediate neighbourhood, this difficulty be really formidable, the reader must judge for himself. The alternative is *submergence* to this extent, and more, with the

various difficulties that attend it. And mere submergence does not account for the phenomena; so there has to be added to it a complicated, and in some points incomprehensible action of icebergs and coast ice and waves of translation! It is a question of probabilities:—whether the deposition of this shelly gravel was the work of land ice, whose work elsewhere it closely resembles, and of whose presence here there is ample other evidence; or of the sea, whose ordinary work it does *not* resemble, and of whose former presence at this level there is *no* other evidence.

The Irish Channel.—Additional light, we think, will be thrown upon the subject if we take a general view of what has been made out regarding the glaciation of the Irish Channel, and the tracts on both sides of it.

There is good proof that during part of the glacial epoch the Irish Channel was filled from side to side by an immense stream of ice over 2000 feet thick. Mr. Horne* found that the ice-sheet at the mouth of the Nith must have been of *at least* this thickness; and there is reason to believe it may have been considerably more—perhaps nearer 3000 feet. This ice, moving southward, was joined by the north lake ice off the Cumberland coast; and the resulting direction of the united stream became south-west. It buried and overwhelmed the Isle of Man, which is striated all over in this direction, viz., from N.E. to S.W. It was in such mass farther south that it held on its way unaffected in any perceptible degree by the ice from the Snowdon range, as Ramsay has shown. According to his observations, the great ice-flow passed straight across the openings of these North Wales valleys; and the island of Anglesey is also striated, not from the adjacent mainland, but from N.E. to S.W.†

When we turn to the other side of the Channel, viz. to Ireland, we find there, from the investigations of the Rev. Mr. Close and others, that part of an immense body of ice, originating in the mountains of Sligo and Galway in the west, moved eastwards and southwards across the country, and entered what is now the Channel near Dublin and Wicklow.‡ Here it joined the other

* "Sketch of the Geology of Isle of Man," *Trans. Edin. Geol. Soc.*, 1874.

† *Quar. Jour. Geol. Soc.*, vol. xxxii., 1876.

‡ Map of the General Glaciation of Ireland, by G. H. Kinahan and M. H. Close, Dublin, 1872.

great ice stream from the south of Scotland and the Cumberland mountains, and must have affected to some extent the general direction of that stream. Mr. Horne believes, from the presence of chalk flints, that the Irish ice at times succeeded, "after a hard battle," in reaching the Manx coast. If so, it must have, to a certain extent, displaced or "shouldered aside" the Scotch and Cumberland ice. He says—"it is not to be supposed that the normal momentum of the respective ice-sheets remained constant. The moving force must have varied with changing conditions." And "the respective ice-sheets must have been subjected to intense compression."* It is, therefore, quite conceivable that, now on this side and now on that, the ice would be pressed up to some extent on the neighbouring land. This is what we believe did happen. The eastern side of the great united ice-stream was pressed up on the hillsides adjacent to the Menai Straits, and the western side was (simultaneously or alternately) pressed up on the hillsides near Dublin and Wicklow. It is in such situations on both sides of the Channel that these mixed and broken sea-shells are found. Can any other likely explanation be given of why they are found at these heights here, and here only?

Submarine Hollow.—This seems to be confirmed, in an interesting way, by the deep hollow which extends along the bottom of the Irish Sea, similar to the submarine hollows in the sea-lochs and along the western coast of Scotland, which Professor Geikie and others have concluded were formed by the ice, wherever its action was intensified, during the glacial period. In the centre of the Channel, between Portpatrick and the Irish coast, there is a great submarine basin, sinking from 80 fathoms to 149 fathoms, *i.e.*, having a maximum depth of 69 fathoms, or 414 feet, more than the surrounding sea-bottom. Again, between the Welsh coast on the one side and the Dublin and Wicklow coast on the other, there is also a well-marked submarine hollow, sinking from 55 to 84 fathoms, thus having a depth of 29 fathoms or 174 feet. This hollow, which, between the Isle of Man and southward to the line of Dublin Bay, dies out a good deal both as to breadth and depth, becomes again broader and deeper just where the ice would be constricted between the Irish and Welsh coasts, and where, as we have seen, it would be receiving considerable accessions on both

* "Sketch of Geology of Isle of Man," p. 23.

sides. It looks as if the preponderating mass of ice, or its centre of weight and motion, had been shifted a little from time to time, now to this side and now to that, the result being to erode a broader channel here than elsewhere. Not only so, but there is a separate little basin near the Anglesey side, as if for a time an increased weight of ice had been compressed to that side.*

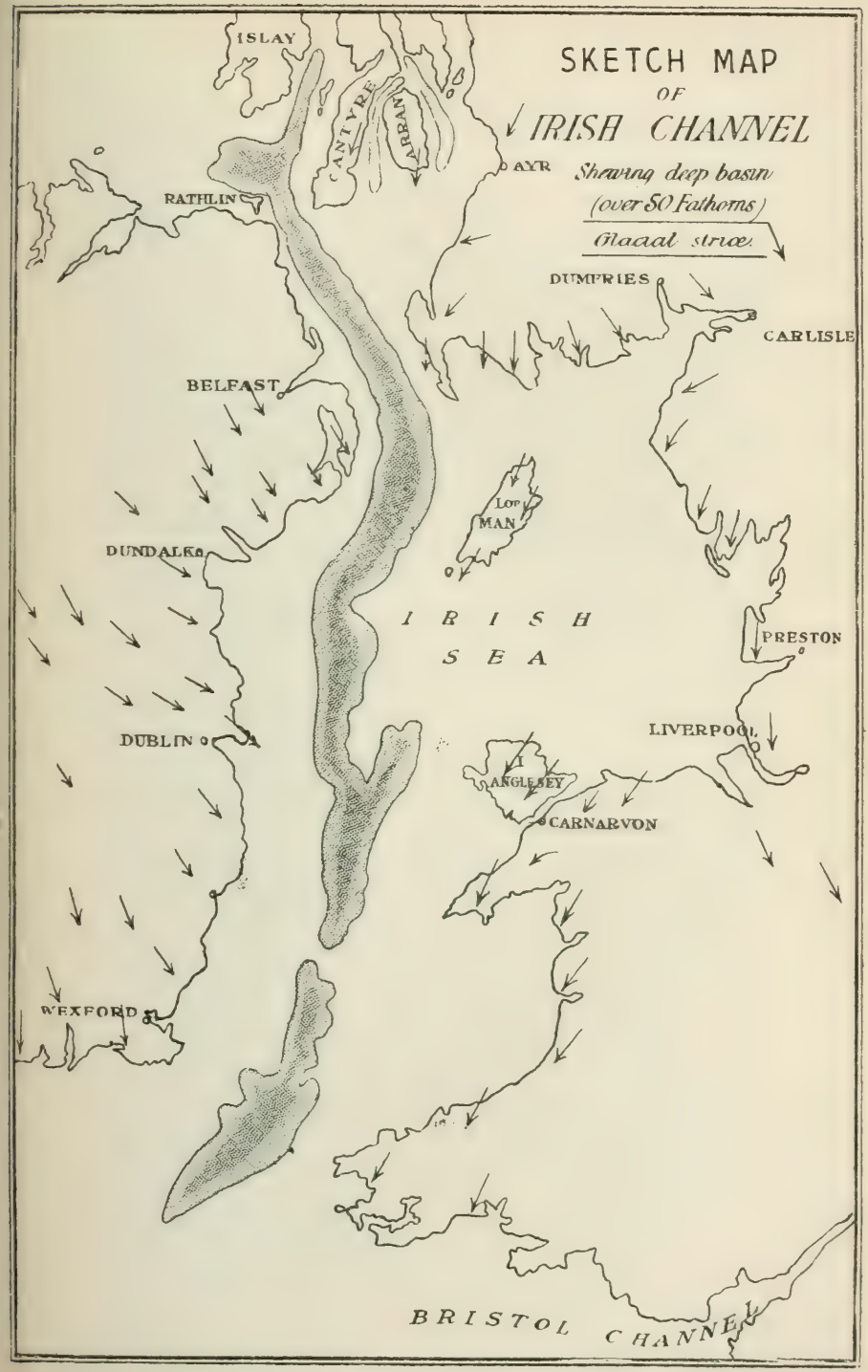
Altogether, we should say that if anywhere ice, moving over what was formerly a sea-bottom, can carry up shells with it on to the adjacent land—of which there can hardly be any doubt, and a number of instances have been already referred to—this, in the conditions indicated, seems to be a locality where such a result would most likely be produced. The characteristics of the shells and of the gravels in which they are imbedded are, as we have seen, quite in harmony with this account of them. So, too, is their position. Not in land-locked or sheltered situations, but in the immediate neighbourhood of the open coast-line, and on hill-sides which, in the circumstances described, would act in some degree as barriers to the progress of the ice. As a rule, marine shells deposited in the usual way are found in well-sheltered basins, bays, and arms of the sea; not on exposed headlands and hillsides, as we are asked to believe they were laid down by the sea in Ireland and Wales. Of course there can be no attempt to show that the position of the shells here would be so sheltered from "ploughing out" or "denudation" as to account in some degree for their being preserved.

Ireland.—We have been referring chiefly to the instance in Wales as that most frequently founded upon; but the instances in Ireland are also worth looking at for a little by themselves.

Ireland consists of a great central plain of Carboniferous limestone, bounded in various directions, but not entirely surrounded, by groups of mountains of older formations, chiefly Silurian schists and granite. A line drawn across the centre of the island, from Dublin or Dundalk Bay on the east to Galway on the west, will nowhere touch a higher elevation than about 250 feet above the sea.† A very moderate depression would, therefore, submerge the greater part of Ireland.

* "Great Ice Age," J. Geikie, p. 519, *et seq.* "Sketch of Geology of Isle of Man," J. Horne. (See annexed Sketch Map.)

† E. Hull, "Physical Geology and Geography of Ireland," p. 121.


SKETCH MAP
OF
IRISH CHANNEL
Shewing deep basin
(over 50 Fathoms)
Glacial striæ
ISLAY
CANTYRE
ARRAN
AYR
RATHLIN
DUMFRIES
CARLISLE
BELFAST
LOP
MAN
DUNDALK
I R I S H
S E A
PRESTON
DUBLIN
LIVERPOOL
ANGLESEY
CARNARVON
WEXFORD
BRISTOL
CHANNEL

To the north of Galway Bay, and close to the western coast, rise the Connaught and Sligo mountains, from which the glaciation of the central part of the island has proceeded.

This central plain is largely covered with what are called the "middle sands and gravels," or more shortly, the "limestone gravel," from being largely made up of pebbles of Carboniferous limestone. Now, recollecting that Ireland was glaciated chiefly by ice proceeding from the mountains in the west, and that near Dublin and Wicklow this ice, approaching the great mass that already occupied what is now the Channel, would have to struggle for a place, so to speak, with that mass—what do we find? The middle gravels rise to considerable elevations [1200 to 1300 feet] at some spots on the flanks of the Dublin and Wicklow mountains, where they are found to contain shells most of which live in adjoining seas. Mr. Close, whose labours in investigating the glacial phenomena of Ireland are well known, supposes the gravels to have been carried thither by *floating ice*, as they contain *pebbles of limestone* and other travelled stones. These limestone pebbles, Professor Hull explains, "must have come *from lower ground*," and he adds that "without some such agent as that suggested by Mr. Close, it is difficult to account for their presence."* This is the same explanation as was given of the transported and uplifted pebbles on Moel Tryfaen; coast ice and icebergs called in to do work which, for our own part, we are unable to see they could perform. Till we meet with some one who can show how floating ice can carry anything from a lower to a higher level (apart from such absurd suppositions as that of its cruising about with its burden for some thousands of years while the land was sinking) we shall hold this Irish shelly gravel found at these heights and composed largely of materials brought from a lower level to be another clear example of the effects of the great sheet of land ice—whose existence is otherwise amply proved—moving over parts of the country that had formerly been a sea-bottom, and rising, where obstacles compelled it, to some height on the adjoining hills; and shall view it as a strong confirmation of what we have concluded to be its effects also on the other side of the Channel.†

* *Ib.* p. 87.

† Mr. H. H. Howorth, in arguing for the deposition of these beds by a "great glacial flood," or "waves of translation," points out that here, in

Thickness of the Ice.—But, we may be asked, is it possible that the ice was in such mass here as to lay down these transported shelly gravels? We think so. There is no doubt it was in mass enough to bury under it the islands of Man and Anglesey, and to pass straight across the mouths of the Welsh valleys, making the local glaciers conform to its flow; also to striate the subjacent rocks on Moel Tryfaen, and bring with it pebbles and larger stones from a far distance and from a lower level. These things have been proved, and we know of nothing else than land ice that could produce such effects. A few particulars, however, may be given on this point.

The minimum slope of moving ice is taken by Dana as 10 feet to the mile. Professor Favre of Geneva estimated the slope of the old Aar glacier towards its termination as not more than 2 in 1000, *i.e.*, about $10\frac{1}{4}$ feet per mile. From a recent article in *Nature* (April, 1889) it appears that the slope of the great Alaska glacier in its lower part is about 13 feet in a mile. Remembering that the stream of ice from the south of Scotland, joined by the Cumberland and Welsh ice on the one side, and by the Irish ice on the other, would have its surface slope well maintained, I think we are justified in taking the average slope of this great body of ice that filled the Channel at about the minimum of 10 feet in a mile. If, therefore, it was some 3000 feet thick, as there is good proof it was, among the mountains of Galloway, then here, say 120 miles south, it would still have a thickness of 1800 feet. The same remarks apply to the ice on the Irish side, which is shown to have been of at least equal thickness,* and the distance traversed by it being about the same.

Slope of Moel Tryfaen.—We may add here that though we have abundant proof that ice, when urged on in great mass, can move up comparatively steep slopes, yet, in all likelihood, the steeper the slope the less chance there is of the ice carrying anything with it. But as regards Moel Tryfaen at least, the fact is that the slope is exceedingly gentle, as will be apparent from the

the narrow part of the channel, the wave would be constricted, and so rise higher on either side. (*Geol. Mag.*, 1883). If so, such must have been the case also in every narrow channel and arm of the sea all round our coasts. But the suggestion is interesting as confirming what we have said regarding the ice sheet at this particular point.

* Close, *Geol. Mag.*, 1867.

following sketch, copied from Mr. Mackintosh's paper in *Geol. Mag.* of January, 1872; so that, when the American geologists speak of stones having been carried up "a slope of 7° two miles long, or 16° one mile long to a height of 1400 feet" (see Appendix)—this is quite analogous to what seems to have occurred with the glacial shelly gravels in the neighbourhood of the Menai Straits.*

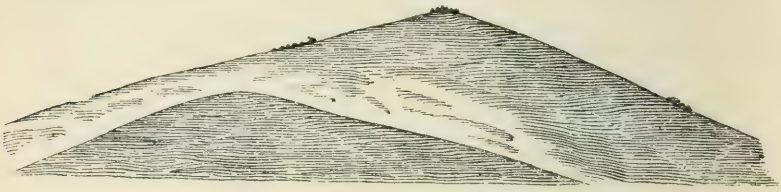


Fig. 4.—Distant view of Moel Tryfaen from near Bangor. Alexandra Quarry to left of summit. [From *Geol. Mag.*, 1872.]

We have thus endeavoured to show that these shelly gravels are very insufficient proof of such a submergence as is contended for, because (1) there is every appearance of their not being in place, and (2) their presence in the positions where they are found can be otherwise accounted for than by actual deposition by the sea at these points. We have also tried to show, from a general view of the glacial phenomena presented by the neighbourhood, how probable this other account of them is. If some readers still find it difficult to accept this explanation of them, then the only alternative is the "submergence." We have already touched on some of the difficulties attending that theory, and there are

* On the second part of his paper on the "Drift-Beds of the N.W. of England and N. Wales," Mr. Mellard Reade says—"Moel Tryfaen is a rounded mound-like plateau forming a spur of Snowdon. It is evident that the Tryfaen gravels are but an upward extension of those on the valley. There are no terraces on Tryfaen. At the Alexandra quarry, just on the summit, is a bed of current-bedded laminated sand and gravel containing large boulders. At about 12 feet from the surface I took out a glaciated stone; the rolled gravel contains travelled granite and even flints. The larger stones appear to be local" (*Quar. Jour. Geol. Soc.*, vol. xxxix., 1883). Mr. A. Taylor, F.G.S., in a paper on "Denuding Agencies," &c., points out that "glacier-eroded lakes, much lower than Moel Tryfaen, and close to it, are free from marine remains; therefore it seems difficult to suppose that a depression of 1300 feet and immersion in the sea of Tryfaen could have taken place without having left any marks on the land except at one spot." *Ib.*, vol. xxxii., 1876.

others which we may now briefly indicate. The more clearly the difficulties in the way of accepting it are brought out, the more is the other explanation which we have suggested strengthened and confirmed.*

Sir A. C. Ramsay on the Dee.—We may gather some valuable collateral evidence from an able paper by Sir Andrew Ramsay on the "Physical History of the Dee."† In that paper, accounting for the formation of the Dee valley (in Wales and Cheshire) by the long continued action of the ordinary agencies of denudation, Sir Andrew maintains that "since the beginning of the Permian epoch, the higher ground of Wales has formed land well raised above the level of the sea," and that "North Wales was carved by slow degrees and by sub-aërial agencies into its present mountainous form chiefly between Permian times and the present day." He passes in brief review the various intervening formations to show how inconsiderable the changes of level probably were while these groups of strata were being laid down. The Permian and Trias he believes to have been deposited in inland seas or lakes when the country stood somewhat higher than now. The Jurassic formations were deposited amid groups of islands in shallow seas. The Purbeck and Wealden beds indicate "fluviatile conditions." The lower half of the Cretaceous formation was "certainly deposited near shore;" and even "during the deposition of the chalk, there is no proof that the higher parts of Wales were submerged, but rather the opposite." Later still come the Eocene deposits, "which in a large sense may be regarded as estuarine;" the Miocene rocks "are unmistakably of terrestrial and fresh-water origin: and the different members of the Crag were mere eastern shallow sea or shore deposits." Sir Andrew thus holds that, since Permian times at least to the close of the Crag, the hilly region of Wales has remained "well-raised above the level of the sea." He keeps up the head of the country, so to speak, during all "that long lapse of geological ages," and then at the end of them all, lets it

* Sir A. Ramsay, alluding to Dr. Croll's suggestion that "the Boulder-clays of Holderness, &c., were pushed forward and left on the land by the Great Northern Glacier that, coming from Norway and North Britain, filled great part of the German Ocean," says frankly, "this is the alternative if submersion is not allowed." "Physical Geology and Geography of Britain," 3rd ed., p. 157.

† *Quar. Jour. Geol. Soc.*, vol. xxxii., 1876.

go down, down, "full many a fathom deep," at a comparatively recent time, immediately preceding our own day! But we are inclined to think that Sir Andrew, in writing this paper, must have given up the "great submergence" during the glacial epoch, for he speaks of it as a "minor submergence." Yet, according to his own former view of it, the whole country, except the higher hill-tops, had disappeared! If this was only a "minor" submergence, may we ask when was there a major?

Here we cannot fail to note how improbable it is—how inconsistent—that the smaller subsidences which have taken place since Permian times, and during which the higher grounds of Wales continued to be "well raised above the level of the sea,"—that these smaller, partial subsidences should form well-marked groups of strata which remain, and can be distinguished to the present day; and yet that a subsidence and re-emergence of the land to the extent of 1500 or 2000 feet both ways,—a total movement which it has been estimated might occupy some 200,000 years,*—could take place, and the deposition of sediment during all that time be so slight that no permanent strata were formed—nothing but some local sporadic beds of sand and gravel, which were afterwards nearly all cleared away!

To what depth, is it imagined, must the land sink, and what length of time is required before any solid strata can be formed?

The Carboniferous period, for example, we can see was one of gradual subsidence; but deposition went on, *pari passu*, so to speak, with the downward movement. The result is seen in those successive beds of sandstone, shale, coal, ironstone, limestone, which make up our Carboniferous formation. Yet it is thought that during the "great submergence," if such there was, of the glacial epoch—when the waters must have been full of sediment from the action of the ice—no deposits were formed but what subsequent *local* glaciers almost entirely cleared away! How was this? Did the land sink and rise again more rapidly at this late geological period than in earlier times? This has actually been suggested by some writers, but it has not the slightest degree of probability in its favour. The reverse is far more likely to be true, viz., that the movement was much slower than in earlier periods.

* "Antiquity of Man," p. 485.

The South of England.—But we have yet another point in confirmation of our position to refer to. It is a noteworthy fact that, as Sir Andrew Ramsay has pointed out, "south of the estuaries of the Severn and the Thames, England is for the most part destitute of boulder drift," only some erratics being found close on the sea, which may have been brought by floating ice.* Lyell also states that "this portion of the south of England cannot be shown to have been under water at the time of floating ice by the evidence of erratics or marine shells of northern species."† And again, "The district south of the Thames and Bristol Channel seems to have remained land during the whole of the glacial period at a time when the northern area was under water."‡ And in his map showing the extent of the supposed submergence during part of the glacial period, all south of a line drawn between the estuaries of the Thames and the Severn is marked by dark lines to represent "the land which alone remained above water."§ If all this be correct, then we have this surprising result—that while "the land north of the Thames and Bristol Channel and that of Ireland was gradually reduced to such an archipelago as is pictured in map"†—that is to say, was submerged till only the summits of the highest hills appeared as scattered islets above the sea,—all south of the Thames and Bristol Channel remained clear and dry above water! In North Wales there was a submergence, at first believed to be 2300 feet, and still maintained to be about 1400 feet, while at a short distance, to the south of the Bristol Channel, this great depression died out or disappeared, so that there was no submergence at all! Is this credible? And it is a curious circumstance that the evidences of glaciation and of a certain degree of submergence go together and cease together; so that while it is sometimes said there is no trace of submergence south of the Thames valley during the glacial period, at other times it is stated there is no trace of glaciation there. Thus, Sir Andrew Ramsay says—"South of Wales, in England, I know of no definite signs of the direct action of glaciers:"‖ and Dr. James Geikie—

* "Physical Geology and Geography of Great Britain," 3rd ed., p. 157.
† "Antiquity of Man," p. 276.
‡ *Ib.*, p. 275.
§ *Ib.*, p. 276.
‖ *Op cit.*, p. 384.

"There is no direct proof that the ground south of the Thames was ever covered with land ice."* It thus appears that where the marks of the ice cease the indications of submergence cease also; which certainly looks as if things taken to indicate submergence were really effects produced by the land ice. We can understand that an ice-sheet may terminate abruptly, and the evidences of its action cease entirely within a short distance of where it must have been in force; instances are common of ice-sheets terminating in cliffs hundreds of feet in height; but can we suppose such an abrupt termination to an actual submergence of the land?—that it could be so great immediately to the north of the Bristol Channel and nothing at all immediately to the south of it—and this without any apparent break or dislocation in the strata along that line?

Those who insist upon the truly marine origin of these shelly gravels on Moel Tryfaen, and hold that they indicate a submergence of the land to that extent, have therefore to explain how it is that there is no trace of such submergence over the south of England, where, be it remembered, there was no "subsequent glaciation" to efface it.

"*Local Depressions.*"—But it is sometimes said there may have been a "local depression" in Wales—a considerable local depression—while there was little to the north of it, and almost none at all to the south of it. This seems to be the last resort of a bewildered geologist. He must surely be at his wits' end when he has recourse to such "local depressions." There is nothing to support this theory—no such disturbance of the recent strata as to show it is even probable. On the contrary, Lyell tells us that "on the borders of Wales and Shropshire, we find the slaty beds of the ancient Silurian system curved and vertical, while the beds of the overlying Carboniferous shale and sandstone are horizontal. All are agreed," he continues, "that in such a case the older set of strata had suffered great dislocation before the deposition of the newer or Carboniferous beds, and that these last have never since been violently fractured, nor have ever been bent into folds, whether by sudden or continuous lateral pressure."† It thus appears there is no evidence in the strata of any such local disturbance since Carboniferous times.

* "Great Ice Age," p. 364.

† "Principles of Geology," vol. i., p. 315.

It would be surprising enough that the whole country should be depressed and re-elevated 1500 or 2000 feet without any apparent disturbance of the strata; but it is impossible to conceive only some parts of it affected in that manner and to that degree without any such results being produced.

Summary.—Such are our reasons for doubting or disbelieving in this alleged "great submergence" during the glacial epoch. We have shown the imperfection of the evidence on which it rests, and its absence over the country generally; that the explanation given of that absence is not satisfactory; that in other countries of the northern hemisphere there is no proof of such a deep submergence as that contended for, or of one exceeding 500 or 600 feet; that in the few exceptional cases where marine organic remains have been found at considerably higher levels than this they bear every mark of not being in place, and are associated with tokens of powerful ice-action, indicating the cause to which their position is most likely due; that this is confirmed by the absence of all traces of such a submergence, during the same period, within a short distance of them; and that no evidence from the strata can be adduced in favour of a "local submergence," which, besides, is in itself in the highest degree improbable.

Some Submergence admitted.—We have shown that there is a very general consensus of evidence in favour of a submergence of 500 feet or thereby. But this is very different from one of 1400 or 1500 feet, not to speak of 2000 feet or more. It seems most likely that this comparatively limited submergence over a great part of the northern hemisphere during the glacial epoch was mainly due, not to an actual subsidence of the land, but to the increase and deepening in these latitudes of the waters of the sea, caused by the attraction of the great mass of ice that was then accumulated in northern regions. Dr. Croll, Sir W. Thomson, and others have shown very clearly that an accumulation of polar ice in either hemisphere would be attended with a certain displacement of the earth's centre of gravity, the result of which would be to raise the general level of the sea towards the pole where the ice was in force. These eminent physicists have made calculations as to the effect which might thus be produced upon the waters of the ocean; and though the results differ somewhat according to the different data which they respectively adopt in regard to the

mass of the ice, or its preponderance at one or other of the poles, yet they generally concur in admitting that a rise in these waters (*i.e.*, a submergence of the land), to the extent of 400 or 500 feet in our latitude, can thus be accounted for.

Here, then, we have a *vera causa*—a real intelligible cause—satisfactorily accounting for the effect, and accounting for it *at that particular time*. For it is not only the submergence, but the *coincidence of the submergence with the glacial period*, that has to be accounted for.* In every part of the world where glaciation has been observed, at least in the neighbourhood of the sea, it is accompanied by evidence of some submergence, indicating apparently a connection between the two. And as manifestly submergence could not produce the ice—to which, indeed, so far as it prevailed, it was distinctly unfavourable—it is probable that the ice was, in this way, the cause of the submergence. This is surely far more likely than that certain movements of the internal heat of the earth, contracting and expanding the rocky masses, (which was Sir C. Lyell's idea†) should cause depressions and elevations of the earth's crust in so many countries, by a curious coincidence, just simultaneously with the occurrence of a glacial period on the surface!

But if this be the cause, of course the effect must be proportional to it. Lyell discarded it because it could not account for a submergence of 1500 or 2000 feet which he considered had to be accounted for.‡ But if it could produce one of 500 feet or thereby, we have shown some reason to hold this would be sufficient. Be it remembered, too, that a submergence of this amount would cover all the lower or alluvial parts of the country, as shown in Lyell's map—*all those parts in which evidences of submergence are certainly to be found.*

* Sir C. Lyell, after describing the shell-beds at Uddevalla, in Sweden, visited by Dr. George Jeffreys in 1862, remarks:—"It appears, therefore, that the series of movements in the district under consideration consisted, first, of a depression converting the shallow water into deep sea at a time when the cold was very severe; and then of an elevation of more than 200 feet when the waters of the sea had acquired their present milder temperature" ("Principles," vol. ii., p. 193). We have thus severe cold and depression, milder temperature and elevation. This looks as if the two sets of phenomena were somehow related.

† "Principles," vol. ii., p. 135.

‡ "Principles," vol. i., pp. 289-291.

Conclusions confirmed by N. America.—Our acceptance of this as the true or chief cause of the submergence during the glacial epoch is greatly confirmed by the light cast upon it from the North American continent. There we find the phenomena on a great scale,—the characters "writ large" and clear, so to speak—free from the complications produced on this side by the meeting of the separate ice-streams passing between islands and over old sea-channels. According to theory, if this be the true cause, the submergence should *increase towards the north.* And this is precisely one of the points observed by the American geologists, and which they have brought out most clearly. Thus Dana states it:—"The height of the sea-border formations increases in going north. On the southern shores of New England the height above the sea is 40 to 50 feet; at Point Shirley, near Boston, 75 to 100 feet: on the coast of Maine, in some places, 217 feet; on the shores of Lake Champlain, at different heights up to 393 feet, and containing marine shells to a height of 325 feet; on the borders of the St. Lawrence, with abundant marine fossils near Montreal, to a height of 460 feet. . . . On the coast of Labrador the beds are 400 to 500 feet above the sea."* And farther north, in the Arctic regions, at higher levels still.

How different is this from what he has to say regarding Britain —that "the depression varied in different parts from 1300 to 500 feet, except over southern England, where it may have been only 100 or 200 feet" (p. 555). There is no sequence or connection here. But if we leave out the 1300 feet in the middle as not proving submergence, the other terms fall into something like uniformity with the facts observed on the North American continent.

This theory dispenses entirely, or in great measure, with any actual movement of the earth's crust during the glacial period, though there may have been, to some slight extent, and from the same cause, an actual depression. The supposition, however, of great local depressions and re-elevations within such a comparatively recent period, is, as we have already shown, in many respects improbable. Some further considerations on this head may be added ere we close.

Movements of the Earth's Crust.—According to the latest investigations of physicists, vertical movements of the earth's crust are of two kinds—(1) Those connected with compression, or which

* "Manual," p. 550.

take place in volcanic districts, and are usually accompanied by earthquake movements and fractures or displacements of the strata, which of course cannot be restored to their original position; (2) Those slow and secular movements, independent of volcanic or earthquake phenomena, and extending over large areas and during indefinitely long periods, which seem to result from certain gradual disturbances of the equilibrium of the crust by the progress of denudation and the accumulation of sediment, or by the heaping up of ice and snow in certain areas.* So far as they may be due to actual movements of the earth's crust, it is evidently to the latter class that the changes of level we have been considering belong. And it is from such slow movements of elevation and depression, observed as taking place in certain parts of the world—in Scandinavia and Greenland, for example—that the measure and comparison of the movements during the glacial period have been taken, and we think rightly taken. It is from these that Sir C. Lyell took the average vertical movement of $2\frac{1}{2}$ feet in a century, from which he computed the time required for the total downward and upward movement during the glacial epoch as some 200,000 years. But we think the error lies in assuming that the movement can go on to 2000, or even 1500 feet. In those countries which furnish the facts on which the calculation is based, there is *no trace* that the movement has gone on to anything like that extent; on the contrary, it appears to be an oscillation or movement of the crust restricted to very narrow limits indeed.

The view that is undoubtedly gaining ground among geologists is that our earth is a planet *with a history*—it is a gradually cooling and consolidating body. Hence many of them believe, what seems very probable from all that is known of its structure, that these movements of the crust have been gradually diminishing in intensity during the ages of geological history. The earlier formations they regard as giving evidence of greater plasticity—of being subject to greater changes, both of depression and elevation, than the later ones. Thus, Dr. Prestwich, referring to the latest changes of level of which we have any evidence, amounting to from 50 to 70 feet, remarks:—"Such is the result of the last of those movements which we have traced through all geological history. Continuous for long periods in the earlier times, and

* See Fisher's "Physics of the Earth's Crust," and Prestwich's "Geology."

productive of settlements to be measured in Cambrian times by thousands of feet, they have gradually diminished in intensity and power, until in the later geological times these great slow continental movements become limited to hundreds, and in more recent times have become reduced to, so to speak, tens of feet, or to a state of comparatively stable equilibrium."*

To the same effect Sir J. William Dawson, in his Presidential Address to the British Association at Birmingham in 1886, states his view that, as a consequence of gradual cooling and contraction, and the foldings of the strata caused thereby, the earth's crust is now thicker and stronger, and its great ribs of crushed and folded rock are more firm and rigid than at any former period. "And thus," he says, "there are enormous physical difficulties to any theory of the alternations of the oceanic and continental areas, except locally at their margins." There has therefore been, he concludes, a general "permanence of the position of the oceans and continents throughout geological time."

This, if we may venture to say so, appears to be a far more rational and philosophical view—more in accordance with geological facts, and with any intelligible theory of the history of our globe—than to hold with M. Hébert, a French geologist, that "the distinguishing characteristic of the Quaternary period is the great intensity and wide extent of these oscillatory movements of the crust of the earth. During all time," he adds, "the terrestrial crust has been subject to slow and incessant oscillations, but they never attained such proportions as during the period referred to."†

It may be so; possibly the earth's crust may remain comparatively quiescent for countless ages, and then begin a series of wide oscillations when touched by colder climatic conditions,—sinking till all but the highest hills are out of sight, and then, strange to say, after scores of thousands of years, regaining its former position, with very little to show for its prolonged immersion! It may be so; all we say is, it seems improbable, and the evidence for it should be clear and strong.

Apparently some writers in geology do not realise how much they demand when they ask us to believe in great depressions of the land, and great changes of level, at such a comparatively

* "Geology," vol. ii., p. 525.

† "Les Oscillations de l'Ecorce Terrestre pendant les periodes Quaternaire et Moderne."

recent time as the glacial epoch. Some of them are ready on the slightest provocation to dip down whole continents beneath the sea, and that not once but several times, to suit the requirements of some favourite theory.*

How different all this is from the sure philosophic instinct of Darwin! In letters to Sir J. Hooker and Sir C. Lyell, given in his recently published "Life," the great naturalist says:—"I must maintain that I have never let down nor upheaved our mother earth's surface for the sake of explaining any one phenomenon. . . I must still think it a bold step . . . to sink into the depths of ocean, within the period of existing species, so large a tract of surface." Again—"It shocks my philosophy to create land without some other and independent evidence." And again, speaking of Forbes imagining a continent extending within recent times to North America, and others requiring one from New Zealand to South America, and even extending to every island in the Pacific and Atlantic Oceans, he says he gets "quite wroth about these supposed continents submerged within the period of existing species."† He grants they "would remove numerous difficulties" that perplexed him, yet he could not honestly admit them. And we know how his determination in rejecting all such "rough and ready" means of explaining the phenomena of the distribution of life, and his patient attention to other causes, were rewarded by rich and fruitful discoveries regarding the means of dispersal available for both plants and animals.

Conclusion.—Let the same wise caution—the same rule of "parsimony of causes"—guide us in seeking to interpret aright the phenomena of the glacial epoch. Discarding these supposed subsidences and re-elevations, these great oscillations, whether local or more general, of the earth's crust in comparatively recent times, and fixing our attention on the *one single cause*—the severe and protracted change of climate, of which we have such abundant proofs, and which *on any theory* must be admitted—let us try whether by means of it, if we but patiently work it out, all the phenomena in question may not receive a consistent and satisfactory explanation.

* It reminds us of De Quincey's story regarding Charles Lamb and his bathing attendants, who were in such haste to immerse him that they plunged him over head three times before he found breath to explain that he "was to be di-di-dipped only once."

† "Life," vol. ii., p. 38, 58, &c.

APPENDIX.—Transport of Boulders from Lower to Higher Levels.

Instances.—In the American Government Report on the Geology of Pennsylvania reference is made to the Oriskany and Helderberg erratics on the sides and crest of the Kittatinny Mountains, where blocks have been carried up a slope of 7° two miles long to a height of 1300 feet; and in another place, up a slope of 16° one mile long to a height of 1400 feet. "The ice has actually borne them to a higher level" (p. xvi.). "The writer found a boulder of Helderberg limestone perched upon the summit of the Kittatinny Mountains which had been lifted more than 1000 feet above its natural outcrop. Another boulder of the same limestone, 20 feet long, lies on the south side of the mountain, having been carried over its crest and several miles beyond" (p. 22). Sometimes, the Report states, boulders have been carried from one mountain to another across an intervening valley; sometimes lifted from a valley to the top of a mountain; and sometimes "carried from one valley to another after being lifted *across* a mountain range" (p. 31). Hitchcock, Dana, and other writers mention as a common fact the occurrence, in North America generally, of erratics at considerable heights, 2000 feet and more above the rock masses whence they were derived; and some of them 150 or 200 miles distant from their parent bed.*

In Scandinavia, where the ice also attained a great thickness, it passed from the Gulf of Bothnia and Jemtland westward, *against* the slope of the land, crossing the Norwegian mountains, and so finding its way into the North Sea. "At Areokutan, Tornebohm found blocks at a height of 4500 feet which could not possibly have come from any place higher than 1800 feet." †

In our own country similar instances are known, though on a smaller scale. In Galloway, for example, Mr. Horne found large erratics of granite on Merrick up to a height of 2764 feet, the highest point reached by the granite *in place* being only 2270 feet. (Geikie, "Great Ice Age," p. 200.)

And we are familiar with rock surfaces striated upwards at various angles, up to as high as 40°, or even more, as in an instance lately disclosed at Bowling reservoir. Other instances have been observed at Lochlomond, Loch Katrine, and elsewhere.

* Dana. "Manual." p. 530. &c. † Geikie. "Great Ice Age." p. 404.

It is quite clear, then, that the ice may be in such mass as to move straight on, over and across ridges that lie in its way, and that when it does so it can carry boulders or anything else with it.

Dr. J. Geikie, in his "Great Ice Age," gives a rather elaborate explanation of "the occurrence of erratics and perched blocks at higher levels than the rock masses of which they formed a part," treating of how stones "apparently travel upwards through the ice," &c. It is no doubt all true, but we think the following diagram from the American Report brings the matter more clearly

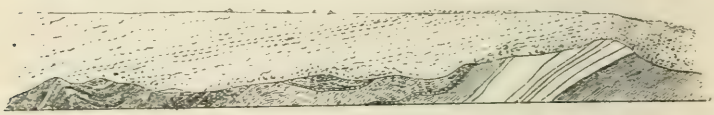


Fig. 6.—Transverse Section of Godfrey's Ridge, Cherry Valley and Kittatinny Mountain at the Delaware Water Gap, showing probable height of the ice. [Reduced from Pennsylvanian 2nd Geological Survey, p. 12.]

before the mind, and enables us to see how the thing took place. The great point is that the ice be in sufficient mass to travel with an easy slope over all the intervening elevations.

Since the foregoing was read to the Society my attention has been called to the fact that similar views in regard to the absence of proof for the alleged "great submergence," and in regard to the true nature of the Moel Tryfaen and other high-level "shelly drifts," have been expressed by several eminent geologists.

I. In the *Geological Magazine* for April, 1889 (published shortly after this paper was written), there is a notice of "The Work of Professor Henry Carvill Lewis on Glacial Geology," by Mr. Warren Upham of the U.S. Geological Survey. Professor Carvill Lewis died at Manchester, July, 1888, in his thirty-fifth year. Though young, he had taken a high place among geologists both in the Old World and in the New. He had given special attention to the glacial drift of North America, and his investigation of the "great terminal moraine" of Pennsylvania and neighbouring districts, published in the Reports of the U.S. Survey, may be said to have "completed the demonstration of the formation of the North American drift by the agency of land ice." On this side of the Atlantic he had made minute and extensive observations on the glacial drift of England, Wales, and Ireland, and had traced the terminal moraines formed by the British ice-sheets over a great part of the United Kingdom. He was, indeed, busily engaged on this subject at the time of his lamented death. Mr. Upham continues:—

"Another very important announcement by Professor Lewis relates to the marine shells, mostly in fragments and often worn and striated, found in morainic deposits and associated kames 1100 to 1350 feet above the sea on Three Rock Mountain near Dublin, on Moel Tryfaen in Northern Wales, and near Macclesfield in Cheshire, which have been generally considered by British geologists as proof of marine submergence to the depth of at least 1350 feet. These shells and fragments of shells, as Lewis has shown, were transported to their present position by the currents of the confluent ice-sheet which flowed southward from Scotland and Northern Ireland, passing over the bottom of the Irish Sea, there ploughing up its marine deposits and shells, and carrying them upward as glacial drift to these elevations, so that they afford no testimony of the former subsidence of the land. The ample descriptions of the shelly drift of these and other localities of high level, and of the lowlands of Cheshire and Lancashire, recorded by English geologists, agree perfectly with the explanation given by Lewis, which indeed had been before suggested, so long ago as in 1874, by Belt and Goodchild.* This removes one of the most perplexing questions which glacialists have encountered, for nowhere else in the British Isles is there proof of any such submergence during or since the glacial period, the maximum known being 510 feet near Airdrie, in Lanarkshire, Scotland. At the same time the submergence on the southern coast of England was only from 10 to 60 feet, while no traces of Raised Beaches or of Pleistocene marine formations above the present sea-level are found in the Shetland and Orkney Islands. The work and writings of Professor Lewis emphasize the principle that glacially transported marine shells and fragments of shells, which occur in both the Till and Boulder-clay and the modified drift in various parts of Great Britain, are not to be confounded with shells imbedded where they were living or in raised beaches, for only these prove the former presence of the sea."

II. In the same magazine (the *Geological*) for 1883 there is a paper by Mr. H. H. Howorth containing several extracts from Mr. Belt's paper, to which reference is made in the passage just quoted. Mr. Howorth is there advocating the theory of "a great post-glacial flood," with which I do not meddle at present; but some of his observations on the subject of the alleged submergence are quite in accordance with those I have ventured to submit. "We must inquire," he says, "how it is that these drifts with shells are not found in the interior of Great Britain, and only in isolated patches along the shore. Surely if the land were generally submerged, as is assumed, even for a comparatively short time only, we should find shell-beds in various parts of England, and not merely in the Severn valley and on points near the coast. In regard to this absence Mr. Geikie says:—'If arctic shelly clays ever occurred in as thick beds in the inland as in the maritime districts, surely we should have found some notable trace of them. It will not do to lay the blame of their disappearance on that geological scapegoat, *denudation*. Denudation has not run

* *Nature*, vol. x. *Geol. Mag.*, Dec. 2, vol. i.—A similar opinion was held fifty years ago by Mr. James Smith, though he attributed the drift to debacles instead of glaciation. *Researches in Newer Pliocene and Post-Tertiary Geology*, pp. 11, 16.)

off with the kames; why should it have been less considerate with the clays? . . . In Norway and Labrador and Maine the shelly clays are restricted, precisely as in Britain, to the vicinity of the sea coast.'" (*Geol. Mag.*, vol. ix.)

Mr. Howorth then goes on to quote from Mr. Belt:—

"Where was the shore of that mythical sea under which England, nearly to the Thames, is supposed to have been submerged? How is it that not a single undisturbed bed of glacial shells has been found, that nearly all are broken to pieces, that many fragments of *Cyprina* exhibit glacial scratchings, and that not a single instance has been recorded of the valves of a Lamellibranch having been found together? Was there no friendly cliff or cavern able to preserve a single shell from the ruthless second advance of the ice?"

What is true of England, adds Mr. Howorth, is true also of Ireland and other places. How comes it, he asks, that no marine shells, except near the coast, are found in the drifts of the Continent? He quotes again from Mr. Belt:—

"Excepting around the northern border of the Baltic, and just as far as, and no further than, the Scandinavian glaciers reached and carried up fragmentary shells from the arms of the sea which they had crossed, the northern drift does not contain sea-shells or any other marine organism. To believe that Europe gradually sank down below the level of the sea until the latter had its shore line more than 1000 feet up the flanks of the mountains, and that it rose again, without the sea leaving behind it any traces of life . . . is an extreme hypothesis, and contrary to all we know respecting the composition of sea-bottoms. . . . There is much evidence to show that vast continental areas were never below the sea level from the close of the Palæozoic period up to the end of the Tertiary period. Yet, after this stability of surface over such an immense period of time, no hesitation is felt, in the comparatively insignificant glacial period, in sending the surface of the land thousands of feet higher that ice may accumulate on the now low ranges, and thousands of feet lower that icebergs may float over the submerged lands; and no difficulty is expressed in believing that it should finish its wonderful oscillations by regaining the level it had before the glacial period commenced! It seems a burlesque on science that such theories should be prevalent amongst our geologists." (*Q. J. of Science*, vol. vii.)

This, expressed with admirable clearness and force, is precisely what I have attempted to urge in the course of my paper. I have only to express my satisfaction at finding that these conclusions—to which I had gradually been led from the best consideration I could bestow on the subject—have been so powerfully supported and confirmed. D. B.

No. IX.—The Surface Geology of Paisley. By the late Matthew Blair.

[Read 10th January, 1889.]

The few remarks which I intend making to-night have reference to the Surface Geology of Paisley—a subject which, in my humble estimation, ought to commend itself to every advanced schoolboy, as well as to every grown man in the community. I shall commence with the locality where we are met,* or rather on the hill behind, which, I daresay, you will agree with me is a good centre to start from.

Oakshaw Hill, as most of you know, is composed principally of Boulder-clay, which contains about the same percentage of boulders as is found in this deposit in other parts of our district. The late Mr. Smith of Jordanhill tabulated them as follows:—

Sandstones, Shales, &c.,	60 per cent.
Traps,	30 ,,
Clay, Slate, and Greywacke,	10 ,,
Granite,	1 ,,

In Paisley and neighbourhood, however, as far as my observation has gone, they are made up in something like the following proportions:—

Sandstones and Shales, including Coals,	50 per cent.
Traps,	33 ,,
Limestones,	10 ,,
Clay, Slate, and Greywacke,	7 ,,
Granite,	10·1000 ,,

I know of only three points where granite boulders have been found—1st, in the Boulder-clay at Mill Street Quarry; 2nd, at a spot where the Canal Railway crosses the road between Paisley and Johnstone; and 3rd, at the excavations for the new dock on the River Cart, on the top of the rock below the brick- or shell-bearing clay. At the latter place there were marine shells adhering to the boulders, three in number, although, in my opinion, they were deposited in the spot where they were found by the action of the drift, or dropped by an iceberg during the later formation. They appear to have come from Ben Awe, the rock of which they most resemble in structure; and the only agency that we know which could have effected this transportation is the agency of ice.

* The substance of this paper was originally read to the Geological Section of the Paisley Philosophical Society.

But to return to Oakshaw Hill; the upper surface is made up of mould or soil about one foot in thickness. Beneath this thin covering, Boulder-clay of a dark bluish or reddish colour is found over the entire surface. Many of the boulders are of a compact nature, being composed of limestone, basalt, and the harder varieties of trap, and exhibiting the beautifully-seen scratches or striations which they must have received during the "Glacial Epoch." Oakshaw Hill appears to be a fair type of the similarly rounded hills in the district. Woodside Hill, Saucel Hill, Hunter Hill, Dykebar Hill, Stanley Hill, Barshaw Hill, &c., are all composed of pretty much the same materials, and no doubt owe their origin to the same order of causes. The Boulder-clay of these hills belongs to two distinct members, and, in my humble opinion, owes its origin to two separate conditions in the region which now forms this tract of country.

The junction between the upper and lower series has been exposed in several cuttings which have been made within the last few years, such as the excavations for the Coats' Memorial Church in High Street. The upper clay is easily distinguished by the tenacity of its matrix, as also by the large percentage of boulders which it holds, of all sizes from small pebbles to blocks of many tons weight. The lower clay attains a much greater depth, although less uniform in its deposition. It is largely mixed with sand and gravel, and contains a much lower percentage of boulders, although those found are as large in proportion as the largest individuals in the upper clay. In some places one of the clays is wanting, the higher resting on the rock, or the higher being absent and the lower underlying the surface soil.

On the south-eastern slope of Oakshaw Hill the Boulder-clay is covered by a layer of sand mixed with a large percentage of mud; it is water-bearing, and is known as running sand. It thins out on the hill, but increases in thickness as it recedes outwards. This running sand passes up into a compact clay known as the *brick-clay*, or shell-bearing clay. It is first seen at the Messrs. Parlane's property, 97 High Street, and is continued eastwards to the river, forming the subsoil of the east portion of High Street, the Cross, and Moss Street, extending southwards to the Infirmary and beyond. It certainly runs out on the face of Saucel Hill at the railway. Proceeding westwards, the shell-bearing clay runs out, as I have said, at the Messrs. Parlane's property,

and re-appears at the Museum: indeed, one of the front pillars has its foundation on a mussel bed. It again disappears at the Coats' Memorial Church, and the Boulder-clay comes to the surface.

In George Street, a little to the south, at a lower level, the rock rises to the surface west of Barr Street, continuing westwards, at a depth of 2 to 10 feet from the surface, until we pass Maxwellton Street, where it dips to the west and disappears. When near the surface in George Street, the underlying Carboniferous rocks disclose, amongst other minerals, a coal seam from 4 to 9 inches in thickness. Maxwellton Street, Queen Street, Cross Street, and Castle Street are almost built on the rock, which comes so near the surface that the foundations of several of the houses must actually be placed on it. As far as my recollection serves me, the rock which lies below Queen Street, &c., is an impure limestone.

Towards the north end of Castle Street, the rock is either covered by, or impinges against, a bed of brown sand, which increases in thickness towards Broomlands and Sandholes, where it becomes the subsoil. I have not ascertained its thickness, but it must be a good many feet.

The strata continue near the surface south of Castle Street until, topped by a massive sandstone, they disappear under Castlehead at the railway. They are again exposed along the Canal Railway eastwards to Camphill, beyond which they dip under the Boulder-clay and shell-bearing clay. Rising again to the surface at Causeyside, they have been cut through by Espedair Burn, forming a valley or ravine, but with this interruption they continue at the depth of a few feet from the surface past Blackhall Buildings to Blackhall House, where they dip eastwards, again rising to the surface in the form of intrusive dolerite and a burnt coal bed at Jenny's Well. During their course there are exposed several seams of shale, coal, limestone, and other strata, which, from the waterfall at the Hammils to the section exposed at Hawkhead Bridge, have a continuous dip to the east or south-east.

When we turn our attention to the north side of Oakshaw Hill, towards the low-lying district of St. James' Park, or the Racecourse, we would expect, from the flat appearance of the surface, that the subsoil would be somewhat uniform. But that is not the case: for although the brick-clay rises on the slopes of the hill at

Underwood and attains great thickness in Caledonia and Love Streets, yet at the eastern extremity of Mossvale Street the Boulder-clay rises to the surface, while at Greenhill Road, also at Fergusliе School and north of Craigiehea, the sandstone rises to the surface. At the latter place it was long quarried for building purposes. On the north side of the Hill a new member of the surface series appears as the subsoil, on the top of the brick-clay, namely, Peat Moss. As far as my observation has gone, this material is not met with in the southern district of the town. It, however, was got in the foundation of St. James' Church, and in several other places in the neighbourhood. Peat, or a substance akin to it, was also met with in the foundation of the New County Buildings at the corner of St. James and Love Streets. It occurs at a depth of 2 feet, resting on the shell-bearing clays. The Boulder-clay retains its normal relative position northwards towards the Clyde, rising to the surface at Laighpark, and dipping as far as the rock will allow it at Nethercommon, where it is covered by the entire series of muddy sand, gravel, shell-bearing clay, upper gravel, and surface soil. The sandstone strata rise towards the east at this point until they reach the surface at Netherhill, where they were recently quarried for building purposes.

The excavations for the new harbour on the River Cart near this spot have exposed a new member of the surface deposits which I have not observed at any other place, neither do I know of it being referred to by any writers on the subject. It consists of a dark brown laminated clay, about 2 feet in thickness, which is deposited on the surface of the Boulder-clay, and is as different from it as a log of wood in a condition of pulp is from a bed of coarse gravel. The laminations are so fine and the contact with the Boulder-clay (which at this place is dark in colour) so sharp, that you can touch the junction with the point of a needle.

This laminated clay follows the sinuosities of the uneven surface of the Boulder-clay, on which it rests, and although in one place the Boulder-clay has its level raised 20 feet higher than at another, this brown laminated clay follows its course, and retains its uniform thickness. It contains very few stones, if any, and, so far as my observation has gone, is as destitute of organic remains as the Boulder-clay it covers. But as I have neither washed it nor examined it with the microscope, I advance no opinion.

The sinuosities formed by the Boulder-clay, and followed by the

brown laminated clay, are filled up with the muddy or running sand, by which it is covered, and the junction between these two is very marked. I have not seen any organic remains in this stratum. It has a thickness of from 4 to 9 feet, with an abundance of concretionary or "fairy" stones. It becomes much more impregnated with mud or clay as it rises to the surface: and although it has a rather uneven bottom, it presents a comparatively level surface for the brick-clay and shell-bearing clay to rest on. This bed of shell-bearing clay, which attains a thickness of from 7 to 12 feet, is covered by a bed of gravel and sand about 4 feet thick, topped by 14 inches of surface soil, much filled with roots. It appears to be made up of sand, clay, and vegetable loam. The Boulder-clay appears to rise and fall, following northward in a general way the surface presented by the strata until a point about a mile above Inchinnan Bridge, where it dips beneath a great deposit of sand, mud, and gravel. It is not touched at a point 500 yards above the bridge at a depth of 60 feet. This immense deposit of mud, sand, and gravel is continued northwards to a point 50 yards from the junction of the Cart with Clyde, where the Boulder-clay again comes up to within 12 feet of the surface, below a bed of sand and gravel. It again dips towards the river; for at the junction of Cart and Clyde, 50 yards further north, nothing but sand is found at a depth of 45 feet.

[At the excavations of the new harbour on the Cart the horns of *Bos primigenius* were found at a depth of 14 feet from the surface; and a few years ago the *scapular bone* of the Irish Elk, *Megaceros Hibernicus*, was found at about the same depth in a clay-field on the west side of the river; and one of the horns of this animal was found at the excavations for the last gasometer which was erected at the Paisley Gasworks. The last two specimens are in the public museum. These remains point to the existence of those animals on the higher portions of our district, when the lower parts (including all the low-lying districts around Paisley) were many feet below the sea, which covered and deposited the materials which make up Greenlaw.]

There can be little doubt that the Boulder-clay underlies this depression, for it is found resting on the strata right under the west end of Inchinnan Bridge, at a depth of 93 feet. The strata dip towards Renfrew for a few hundred yards north-east, close to

the spot where the Earl of Argyll was taken prisoner in the year 1685. The depth of the alluvial soil is 95 feet.*

You will thus note that, from a point about a mile-and-a-half from the junction of Cart and Clyde, the Boulder-clay has a dip of not less than 80 feet from south to north, when it again appears at a single point 12 feet from the surface, and afterwards disappears beneath the sands of the Clyde. This points to a different condition from that in the neighbourhood of Paisley, and leads to the conclusion that long after the last elevation of the land, which raised all the low-lying parts of the town above high-water mark, that portion of the River Cart to which I have alluded formed either part of a deep lake or an arm of the Firth of Clyde which extended well up to Paisley, and which certainly did extend eastwards above the spot where Glasgow Bridge now stands, and before it got filled up by the detritus from the higher parts of the valley.

But what of the brick-clay with its arctic shells, which forms such a large part of the subsoil of nearly all the low-lying streets in Paisley? It would appear to have been deposited long before the last elevation of the land, when the lower parts of the town were not less than 60 to 80 feet below a sea in which were deposited stones and mud by means of floating land ice or icebergs, the chief part of the materials being derived from the washing down of the Boulder-clay from the higher lands, some districts of which have been almost denuded of all the Boulder-clay that they ever possessed.

But it would appear that many ages before the period of which we speak, from the evidence to be found on our highest mountains, the entire area of Scotland was probably submerged to a depth of

* I may relate an incident connected with this spot which occurred in 1832. In the summer of that year a number of unemployed weavers were engaged removing sand from the bed of the river at the lower portion of Colin's Isle. At about 3 feet from the surface one of the weavers dug up a silver shoe-buckle about the size of the palm of one's hand. It had a crest on it. The find was taken to Paisley and offered for sale to a silversmith, who refused it. It was afterwards offered to another, who weighed it, and gave the weavers 7s. 6d. for it. He broke it with a hammer before their eyes, put the pieces into a pot, and the weavers adjourned to a public-house and drank the money. Had this ornament any connection with the Earl of Argyll, who, being pursued during the Monmouth rising, crossed the river about this spot on foot, was taken prisoner at the spot indicated, and was afterwards executed at Edinburgh?

not less than 2000 feet, during which period the upper division of the Boulder-clay was deposited.

Before this great depression took place, or during its earlier period, and during much more intense conditions of cold than afterwards prevailed, the great ice-sheet covered the land to a depth as great or greater than that of the waters by which it was succeeded. The ice may have been so thick as to have displaced the water outwards in all directions from what is now our borders, denuding every material over which it pushed. It is to this ice-movement that we ascribe the striated surface of the older rocks when their surface deposits were first removed; and, in my humble opinion, it was during this period that the nucleus at least was formed of those mounds of sand and till which form the interior of the green rounded hills which go so far to diversify our district and impart to our landscape its principal item of beauty.

Before proceeding to look at the eastern district of Paisley, I would point out the ridge of rocks at the Hammils. The platform which forms the south bank of the Laigh Linn consists of a fine-grained sandstone, the thickness of which I cannot give. This sandstone is topped at the Craigs, which form the north margin of the High Linn, by a seam of soft shale about 1 foot thick, which is covered by about 1 foot 6 inches of a harder material. It appears to contain a large quantity of iron, being what I would call a ferruginous shale, and the series is covered by a bed of coarse-grained sandstone, about 6 feet in thickness, which forms the bed of the upper portion of the river at this point. The continuous removal of the soft shale by the overflow of water has caused the ridge to retreat southwards through the undermining of the upper strata, and there can be no reasonable doubt that at one time the entire series extended northwards in line with the fine-grained sandstone, which then had an elevation of not less than 20 to 26 feet above the level of the lower part of the river. The dip, as I have already said, is towards the south, and the retreat of this escarpment is as sure an indication of the age of the river as days measure out the length of a year, or years the length of a century. Geologically considered, the age of the lower part of our river is of recent date. Compared with such rivers as the Elbe and the Rhine, it is an infant of days.

In crossing the river, we shall first look at the foundations of

the Town Hall. The southern half of its west front is on the Boulder-clay at a depth of 37 feet from the surface. When the excavations had been made 22 feet below the bed of the river the clay was as dry as the floor of a room. The northern half, which contains the clock tower, is founded on a crystalline dolerite at a depth of 28 feet from the surface. This rock forms an intrusive bed which lies parallel with the other strata, and is covered by a seam of shale of from 1 to 2 inches thick, with a coal-bed above it, which was so pure that it was used, so far as obtainable, for fuel to fire the engine of one of the cranes which was working at the excavations. The coal is covered by a bed of calcareous shale, which increases in thickness northwards as it disappears under the street at "Old Smithhills." The usual series of mud, sand, clay, and gravel bring the alluvial soil to the surface, near which were found a considerable quantity of hazel-nuts.

Crossing over to the Abbey Church, we find that the west gable has taken a swing from the perpendicular. This was accounted for by Mr. Salmon, the architect who had charge of the restorations, by the presence of a bed of peat which passes under the foundation. This peat, however, rests on a bed of sand and clay which appears to have been deposited in its present position by the rush of water which was forced over the Craigs on the opposite side of the river at periods when it was in flood. The great rush of water at this spot over an escarpment of not less than 20 feet must have diminished in later times as the rocky face retreated backwards, allowing the peat, which at that time covered the district to the north, to creep over the sand; and the presence of the latter, in my opinion, will better account for the unstable foundation on which the Abbey is built. Even in later times, when St. Mirren preached to the inhabitants of Strathgryffe, and built them a place of worship, he was doubtless attracted to the place by its surprising beauty; and in still more recent times, Walter, the first Steward, when selecting the spot to found the present church, must have been attracted as much by the beauty of the place as by the legendary traditions of St. Mirren. The water which at present constitutes the impure stream is perhaps not one-fifth of what made up its volume in its palmy days, before so much of it was diverted to supply the south side of Glasgow, and retained in great ponds, was dammed up against times of scarcity, to be afterwards sent down the Clyde in a polluted condition.

When the water flowed in its pristine beauty over the rugged escarpment which extended right across the present site of the Infirmary, with the Saucel Hill, wooded to the top, for a background, and trees fringing the stream on both sides, the green sward sloping from the church to the river's brink, and the pure water, alive with perch, flounder, trout, salmon, and the pearl-bearing mussel, which was exported to different countries—the scene on a summer Sabbath-day must have been as refreshing to the bodies of the parishioners and pilgrims from distant parts of the country as the truths taught within the walls of the church were grateful to the minds of the worshippers.

Passing further east, we are met by the intrusive dolerite, which appears near the surface in Abbey Street. This rock cannot extend further west on its present level than Bridge Street, as is proved by the underground passage extending between that street and the river. This passage appears to have been constructed entirely in alluvial soil, for the dolerite appears near the surface at the east end of Abbey Street, underlying Thread Street, Bank Street, and Gauze Street, and rising to the surface at Mill Street.*

It appears somewhat peculiar that this rock should form such an abrupt side to the west boundary of Mill Street, and at first I came to the conclusion that it had been faulted; but Mr. Clark informs me that it was quarried about 90 or 100 years ago for building purposes, a fact that accounts for its absence. Several of the houses on the west side of Mill Street have their front walls built on the dolerite, while the back walls are resting on forced earth; and one or two which have been recently built in this position are showing signs of subsidence, which is not to be wondered at. This bed of dolerite extends eastwards until we come to the magnificent opening at the workings in Mill Street

* There was a legend current 50 years ago—long before the passage was discovered—that in the days of Mary Queen of Scots there existed an underground passage which extended from the Abbey to Crookston Castle. But the presence of this bed of intrusive dolerite interposes an insurmountable barrier to the existence or extension of the underground passage much farther eastward than Bridge Street. The late Mr. Semple proved the reputed residence of Mary Stuart at Crookston Castle to be a myth, for he tabulated every day she spent in Scotland, from the day on which she landed at Leith until the day she fled to England, and he could not find one single day on which it was possible for the Queen to have been at Crookston Castle!

Quarry. It does appear strange that, while strangers coming from distant parts of our own country and from other countries exhibit the greatest interest in the examination of those marvellous surface striations on the rock and the boulders which acted as tools in the production of them, comparatively few of even our intelligent townsmen have ever seen them, although their presence suggests as much to the reflective mind in this country as the Alps suggest to European travellers or the Andes to South American ones.

The section at the quarry consists of—

Surface Soil, - - - -	1 foot 5 inches.
Upper Boulder-clay, - - -	3 to 4 feet.
Lower Boulder-clay, - - -	6 feet 8 inches.
Intrusive bed of Dolerite, - -	25 ,,
Burned Coal, rendered columnar, -	4 inches.
Argillaceous Shale, - -	upwards of 10 feet.

At the foundation of the stalk of the Seedhills Finishing Works the Boulder-clay was found rising to the surface at an angle of about 20 degrees. The sand, shell-bearing clay, and gravel, all lie in their proper order at the same angle. It looks as if the series had formed part of the slope of a hill of which the top had been cut off, the ground being comparatively level for a considerable distance round the spot.

The construction of the common sewer which was recently formed in front of Greenlaw Church, at a depth of 16 feet, started from Glasgow Road in the Boulder-clay which forms the subsoil for the entire distance until the slopes of Greenlaw are reached, when its surface is covered by the entire series of upper deposits. Indeed, this hill appears to consist entirely of, and owes its elevation above the surrounding subsoil of Boulder-clay to, these deposits, which rest in a perfectly horizontal and isolated position.

Proceeding a little further to the east, we come to that interesting section which has been so perfectly exposed by the opening up of Arkleston Tunnel. Before making any statement about this section, I would draw attention to the north bank of the railway, from the bridge over the line west to the signal-box. The weathered limestone stratum in this bank exhibits a richer variety and more abundant quantity of delicate organisms than I have yet seen in any section of these deposits. This section was closed about ten years ago, and has since got a large covering of

the débris placed over it. But from the exceptional interest of the deposit I think it well worthy of being noted in a paper such as this.

When passing through the railway cutting at Arkleston, we can all see that the section has been faulted upwards at its western extremity to an elevation of not less than 70 feet. The section is a perfect counterpart of the Mill Street Quarry, with this difference—that it has a different elevation and dip. I might also add that the dolerite is not nearly so pure as it is at Mill Street. At the lower part of its western exposure, it has caught up large quantities of the "blaes" in its mass. Large sections of the altered dolerite (or "white horse" of the miner) pervades it in places from top to bottom, while it has caught the upper portion of the coal-bed in pockets at its upper surface. I had considerable difficulty for several years in assigning the various exposures of this dolerite to the same horizon, there being nothing on the upper surface of the Mill Street rock except a few patches of the burned coal where that had been spared by the grinding of the ice-sheet. But within the last year a new stratum was discovered at the east end of the quarry which had just been uncovered, and on examination I found it to consist of an impure limestone, about the same thickness as that which covers the iron pyrites at Arkleston: also, a thin bed of the pyrites, which, although only a very thin seam, goes, I think, to prove that the strata are identical, and that between these two places, about a mile apart, the dolerite has been intruded through the same coal strata. I would also state that the greater purity of the dolerite in the exposure at Mill Street, as also its greater density and compact form, may be due more to differences in the rate of cooling than to variations in the mineral composition of the rock itself.

I have now taken you to the eastern boundary of the Burgh of Paisley. Before closing, however, allow me to make a few observations on its western extremity.

In the neighbourhood of the new spinning mill erected at Ferguslie by Messrs. J. & P. Coats there have been several openings made and bores put down, so that the Surface Geology of this district is better known than it had been previously. The section to which I shall confine my remarks is on the slope of one of those rounded hills to which I have alluded, and immediately to the south of what is known as the Green Road. The rock is

usually struck at an elevation of from 27 to 30 feet above sea-level, and is generally covered by the Boulder-clay. But in a section a little south of the old Glasgow and Ardrossan Canal, now converted at this place into a reservoir for the mills, there are only 8 inches of broken rock on the top of the bed-rock, the Boulder-clay being quite absent. Above the broken rock there is a deposit of sand and gravel 3 feet 7 inches, and over this we have a bed of fine clay 6 feet 6 inches, which is topped by 1 foot of muddy clay, increasing into a bed of muddy sand 2 feet 6 inches thick. This is covered by a bed of pure sand, 7 feet 6 inches; sandy gravel, 1 foot; gravel, 1 foot 3 inches; sandy clay, 1 foot 6 inches; surface soil, 1 foot 2 inches; the entire section representing 26 feet 11 inches of surface deposits, and being something like what we should expect, with the exception of the missing Boulder-clay.

But 100 feet further south, at an elevation of 6 feet 6 inches above the former section, we have the following, commencing at the surface—

Sandy Surface Soil, - - -	2 feet.
Sand, - - - - -	5 ,, 2 inches.
Sandy Gravel, - - - -	1 foot 6 ,,
Boulder-clay, - - - -	24 feet 8 ,,

You will remark that the five lower members are absent, their place being taken by the Boulder-clay. I have not taken the broken rock into account, as I consider it the remains of the Boulder-clay. Now, you have here eight distinct deposits sharply marked, and occurring at heights now ranging from 30 to 59½ feet above high water. This last section does not show the highest point indicated by these deposits, as behind the chimney-stalk of the spinning mill there is a bed of sand mixed with clay which at an elevation of 73½ feet above sea-level tapers to a point on the face of the Boulder-clay, which rises from below the newer beds and forms the subsoil of the top of the hill several feet higher. This 73½-feet level is, therefore, the highest point at which I have been able to trace the sea in recent geological times in our neighbourhood.

[The author died on 19th February, 1889, in the 57th year of his age, a few weeks after reading this paper at the January Meeting of the Society. See notice in the *Proceedings*, March, 1889.]

No. X.—The Great Ice Age in the Garnock Valley. By John Smith, Kilwinning. With Four Plates. [Nos. VI. to IX.]

[Read 9th January, 1890.]

The Garnock Valley, situated in the northern division of Ayrshire called Cunningham, is bounded on the W. and N.W. by the range of hills which begin a little to the north of Ardrossan and stretch in a northerly direction for a distance of 11 miles, then wheel round towards the E. and continue nearly to Lochwinnoch. On the E. the valley is bounded by the low ridge which forms the watershed between the Lugton and Glazart Waters, and on the N. by the Lochliboside and Beith hills. Between Kilbirnie and Beith the valley continues in a N.E. direction past Lochwinnoch, Johnstone, and Paisley, the col at Kilbirnie Loch being 94 ft. above sea-level. In the N.E. corner there is another opening through Lochlibo towards Barrhead, between the Lochliboside hills and the high ground E. of Ouplawmoor. In this direction the ground—500 to 725 ft. above sea-level—is lower than on the N.W. side of the valley, but the watershed is higher by some 300 ft. From its peculiar position, defended on its N.W. side and partly on its W. side by hills rising to 1260 and 1710 ft., the cols between which are at no part perhaps less than 1200 ft., except in the narrow pass through which the Largs road runs at Muirhead and Blairpark, where the watershed is about 900 ft., it seemed to present a very favourable field for the study of boulder dispersion, more especially of those boulders whose parent rock is situated somewhere in the Highlands, as this rampart of hills would form to a certain extent a barrier to any ice-sheet approaching the Garnock Valley from a N.W. direction, or, in other words, from the Highlands. Anyone who takes his stand on the high ground to the N.E. of Kilwinning and looks towards the N.W. will understand the full force of these remarks.

This last summer (1889), from the long-continued dry weather, the water in the streams having fallen to an unusually low level, I took the opportunity of examining all their channels with a view of working out not only the foreign but the local boulder dispersion, not forgetting at the same time to note boulders built into fences, lying in fields (precious few now) and on hills, hillsides, and roadsides. The results of the various traverses I made have cer-

tainly been in the highest degree interesting and instructive, and, without going too minutely into detail in regard to the various boulder records, I have no doubt that they will be of great interest to the student of geology in general and to the glacialist in particular.

Commencing, then, at the lowest reaches of the Garnock where boulders have been found, our first record will be two dolerite blocks about 10 cwts. each, well-rounded, striated, covered with *serpulæ*, *balanæ*, *polyzoa*, and *spirorbis*, and imbedded in sand 26 ft. *below* sea level and 9 ft. above the top of the Boulder-clay. They were got in the sinking of Misk pit, and I may say once for all that these two blocks are the only known ones in the Garnock Valley that to a certainty have been carried by icebergs, with the exception of certain blocks near Smithston House and near the source of Redburn, which will be referred to in their proper places.

The estuary of the Garnock for the first three miles from the sea, ebbing and flowing as it does over the Raised Beach beds of sand and gravel, has no boulders exposed along its surface. The surface beds at Misk are 42 ft. thick, including 7 ft. of Boulder-clay, and are all below sea-level. The fossils from them, collected by myself when Misk pit was being sunk, have been described by Mr. David Robertson in the *Transactions*, vol. v., part 2, and show that the stratified clays and sands on the top of the Boulder-clay belong to the Glacial or Post-tertiary series. On the Bogside side of the estuary are a series of rusty sands and gravels some 20 ft. thick, above sea-level, and belonging to the Raised Beach series of beds, but at this part entirely devoid of organic remains. Opposite Bog farm the estuary first begins to flow on Boulder-clay, which is only seen in the bed of the stream when the tide is low. At this part are a few boulders, of which the following may be noted:—Four specimens of grey porphyrites (15in.); purple porphyrite with grey felspar (2ft.6in.); and *red sandstone with white globular patches (10in.), opposite Bogend; *grey "white horse" (5ft.), 6 feet above river, opposite Nethermains. At Dykehead, near mouth

* Boulders foreign to the valley are marked with an asterisk. Some porphyrites, dolerites, &c., may have been brought from districts at a distance, but it is impossible, for me at least, to distinguish them from blocks belonging to native rocks. I may say that where one measurement is given the boulder is roughly globular or of small size, and where two measurements are given the depth has not been ascertained from the boulder being partially buried.

of Redburn, a great number of boulders are seen in the river bed, dolerites and anamasites, up to 3ft. diam., a few porphyrites, sandstones, limestones, and some dolerites with green saponite. A fine boulder of greenstone has been "slaughtered" by some vandal boring a deep shot into it, a fragment measuring 7ft. × 6ft.; grey "kingle" (4ft. × 3ft.) with rounded corners. Kingle is a mining term applied to a very hard variety of sandstone. The parent rock may have been rendered hard by having been in contact with a trap dyke or float, or by having been impregnated by certain carbonates (lime, iron, or magnesia). See J. Wallace Young's papers in volume ii. of the *Transactions*. There are not a great many boulders from Dykehead to Kilwinning bridge, but the following may be noted:—Blue crinoidal limestone (4ft. × 3ft.), tabular, with rounded corners; this rock is from a bed some distance above Beith white limestone; greyish "white horse" (3ft.). White horse is a mining term applied to a very light-coloured (sometimes almost white) variety of trap, some specimens containing as much as 10 per cent. of water. Felspar porphyrite with specks of red saponite (2ft.); *grey grit with $\frac{1}{16}$ inch quartz grains and fine horny patches (2ft.2in. × 22in. × 10in.); clayband ironstone (13in.); *mica schist with layers of quartz (15in.); purple felspar (15in.); green porphyrite with light-green felspar (15in.); *greywacke with glassy quartz (16in.); *red sandstone conglomerate with quartz pebbles up to 1in.; crinoidal limestone (3ft.6in. × 3ft.), flat; anamasite with hornblende (5ft.6in. × 2ft.6in.); blue Beith limestone (3ft.6in.) flat. A lot of dolerites, anamasites, limestones, and a few porphyrites (under 3ft.); these are all about Dirrans. Here, and just where the bridge of the Lanarkshire and Ayrshire Railway is being built on the south side of the Garnock, was exposed the bed containing Post-tertiary glacial shells, the found for the piers passing through it. See Mr. David Robertson's paper in *Transactions*, volume v., part 2. Passing while the lade to Small's sawmill was being cleaned, I saw numerous specimens of *Tellina calcarea*, &c., thrown out, proving the extension of the glacial shell-bed in this direction. *Contorted mica schist (11in.) with $\frac{1}{8}$in. quartz grains; porphyrite with white blotches of felspar* (3ft.9in. × 2ft.4in.); *vein-quartz with green patches (12in.); dolerite (3ft.); *mica schist (16 in.).

This brings us to Kilwinning dam, where a large quantity of boulders have been gathered together from the bed of the stream,

and probably from the fields, to form the dambreast. The most noteworthy are four well-rounded boulders of *Ben Cruachan granite, three of them (10in., 14in., and 16in.); and one (22in. × 14in.); *three contorted schists (14in. to 17in.); *fine-grained grey grit (15in.); *grey grit with $\frac{3}{8}$in. glassy quartz grains (2ft.2in. × 1ft.4in.); *grey grit with $\frac{3}{8}$in. common quartz (2ft.7in. × 14in.); sandstone (20in.); *schist (14in.); amygdaloid (14in.). A little distance below the dam are *fine-grained grey grit (4ft.7in. × 3ft.) flat, which has been blasted; *fine-grained grey grit with $\frac{1}{2}$in. glassy quartz (2ft.6in. × 1ft.4in.); *green schist; *greywacke (12in.); white Carboniferous chert (2ft.3in. × 12in.). Here the Boulder-clay is about 40ft. thick above the river bed, but its base is not seen. Some distance above the dam, and 100 yards below the L. and A. railway bridge, is the largest granite block in the valley—*grey granite, with no large mackles (4ft.6in. × 4ft.), and very well rounded. Near it, *grey grit with $\frac{3}{8}$in. quartz (4ft.9in.), with a little mica and some quartz veins; *grey grit with $\frac{1}{2}$in. milky quartz (2ft.2in. × 19in.); also a lot of dolerites up to 4ft. diam., and a few smaller limestones and sandstones. At and near this bridge are:—grey porphyrite (2ft.6in.); Beith blue limestone (4ft. × 3ft. × 3ft); *contorted mica schist with irregular quartz layers (5ft.9in. × 3ft.4in. × 3ft.); Beith or Auchenskeith blue limestone (5ft. × 3ft.); dolerite (6ft. × 2ft.6in.); greenstone (5ft. × 4ft.); Fergushill Ha' dolerite (5ft. × 2ft.6in. × 1ft.6in.), at foot of Groatholm. Here a section of red, black, and grey alluvial sand and gravel (10ft. thick) is seen on the riverside. Lower Carboniferous limestone *in situ* near G. and S.-W. railway bridge, and in river opposite old kiln; large boulder in centre of river; a few small dolerites and limestones; *? reddish-brown sandstone (6ft. × 4ft.6in.) resting on lower blue Carboniferous limestone *in situ* near Cartleburn; blue Beith limestone at mouth of Cartle Burn (6ft. × 5ft.); another a little smaller. Above Groatholm farm bridge are seen laterite and compact grey ash-beds *in situ*. And below Dalgarvan mill are a few dolerites, some over 4ft., and some smaller porphyrites. From Dalgarvan to Kilkush boulders are very numerous, especially opposite Monkcastle, and Boulder-clay seems to have been pretty thick here before the River Clyde cut its way through it. It seems to be a general rule, although there are exceptions, that where boulders are numerous Boulder-clay has been thick. A lot of dolerite

boulders are built into Dalgarvan dambreast, some over 4ft. and one over 6ft. *Grey grit (18in.); porphyrite (6ft.6in. × 6ft. × 4ft.); another about the same size; purple felstone *in situ* at Dalgarvan dam; very weathered green dolerite, eaten into cavities, with much pyrite (the cause of weathering) and some biotite (2ft.). Near Dalgarvan old dam is a greenish kingle *in situ*, highly-inclined and dipping S.E.; green dolerite below old dam (5ft. × 4ft.); *contorted schist with contorted quartz layers (4ft.6in. × 3ft.4in.), on east bank of river; dolerite, same as Wee Craig (6ft. × 4ft.3in.); a few smaller porphyrites and white sandstones; *siliceous grit with ¼in. quartz (3ft.9in. × 1ft.8in.); dolerite, same as Wee Craig (7ft. × 4ft.6in.); dolerite (4ft.6in. × 4ft.); *close-grained tough greywacke (2ft.6in. × 20in.); anamasites (6ft. × 3ft.6in.); agglomerate, *in situ*, in highly-inclined beds at Dalgarvan old dam; *mica schist (2ft.5in. × 2ft. × 1ft.); *a few vein-quartz pebbles up to 6in.

The Wee Craig. This is a conspicuous boulder of fine-grained dolerite, with black glittering crystals of hornblende, standing in the river near the mouth of Monkcastle Burn (8ft.8in. × 6ft.); *chlorite schist with fine muscovite (19in. × 11in. × 5in.), opposite mouth of Bombo; dolerite with red and green spots (4ft.3in. × 2ft.6in.); limestone (7ft. × 4ft.), flat; *fine-grained green greywacke with $\frac{1}{16}$in. glassy quartz (3ft.2in. × 2ft.6in. × 1ft.4in.); section of bluish Boulder-clay near Bombo mouth, 20ft. high, base not seen; white sandstone (3ft.6in. × 2ft.6in. × 1ft.6in); rolled furnace slag in river gravel; sandstone (4ft. × 2ft.6in.); a few traps near mouth of Caaf. From Caaf Water to near Kilbirnie station the Garnock inclines to the E. side of valley. This appears to be caused by the Caaf, Rye, and Pitcon Waters shoving it over in that direction, as they run with considerable velocity from the hills. Monkcastle escarpment rises to a height of about 200ft. above the Garnock opposite Kilkush, and is a true crag face. A lot of boulders are built into the wall along the side of the Garnock at south side of Dalry. Dalry appears to be situated on a large drum of Boulder-clay, probably 60 or 70ft. thick, and which has a steep face towards the N.E. and a long sloping tail towards the S.W. At the bridge there are a few trap blocks under 4ft., and one limestone. A lot of boulders are built into Biggart's dam-breast, mostly dolerites, anamasites, and a few felstones. At Biggart's dam the Boulder-clay is about 30ft. thick, base not seen;

a few boulders of dolerite, (3ft.); limestone, (3ft.); sandstone (4ft.). On right and left of the Garnock, at Pitcon and Carshead, are large conspicuous drums of Boulder-clay. No Boulder-clay sections from here to Davidshill. A few boulders here and there along the river sides, where they have evidently been brought to protect the banks. The Garnock opposite Hagsthorn passes over the site of a filled-up lake, the bottom of which is at some parts on about a level with present high-water mark, and the deposits filling it are composed of mud, or sandy mud, to a depth of about 80ft. In some parts of this hollow there is not a vestige of Boulder-clay.

At Davidshill 20ft. of Boulder-clay is exposed on each side, with here and there a few blocks of sandstone, limestone, and a few quartz pebbles up to 5in. diam.; *greywacke (2ft.5in. × 14in. × 9in.); a few boulders at mouth of Powgree Burn, near Kilbirnie station; a few opposite Glengarnock houses; bluish porphyrite (6ft. × 4ft.); a few traps below bridge. There are not many boulders from the bridge to Kilbirnie. A short distance above the bridge is a considerable face of Boulder-clay, 20ft. thick, along the east side of the stream. The stones in it are mostly small, only two large ones being exposed—one sandstone and the other a limestone, at 6ft. from top. *Balmaha (?) red sandstone conglomerate (9in.); Boulder-clay (18ft.); only one large boulder, a fine-grained grey limestone. At this point the Garnock bids fair to find its way into Kilbirnie Loch some day, and flow thence to the Clyde. *Greywacke with quartz veins (8in.); *hornblendic felsite (8in.), very hard and well rounded; *Ben Cruachan granite with large felspar mackles; beautifully contorted mica schist (2ft.1in. × 21in. × 9in.). Both of these are close together at the riverside, south end of Kilbirnie. As the above is the last granite I observed in the Garnock, I may say that the height above sea-level is about 120ft., but as the Boulder-clay at this place is 30ft. thick above the stream it has probably been at a higher level. It has again to be remarked that the stones in the Boulder-clay at this point are mostly small.

Between this and the north end of Kilbirnie boulders are not numerous. The following were noted:—A few fine-grained limestones; bluish felstone with green spots (5ft.); a few boulders at first dam, the water being extremely dirty. A trout that could not live, and a large eel in same condition. Kingle (3ft.3in. × 20in.); *hornblendic felsite (4½in.), which may have been brought from

higher up the river, but foreign to the district. A lot of dirty boulders in second dambreast :—Fine-grained dolerite (5ft. × 4ft.): *quartz with mica (10in.); green dolerite (4ft. × 3ft.6in. × 2ft.) with light-green felspar; limestone composed of small crinoids (3ft.9in. × 2ft.); a few small greywackes; some fine amygdaloids, all the cavities filled with calcite; small bank of Boulder-clay with imbedded block of sandstone *on end* (5ft. × 20in.) (see Plate VI., fig. II.); sandstone (12ft. × 4ft.6in.); sandstone with barite (7in.).

The bed of the river a short distance above Kilbirnie is filled with beautifully clean gravel of large size, but there are few boulders. *Quartz with green patches (6in.); a few smaller ones: a section of muddy peat, 1ft.6in. thick, overlaid by 4ft. of river gravel; purple felstone (3ft. × 2ft.2in.); limestone composed of small crinoids (3ft.); barite (5in.); *fine-grained greywacke (9in. and 11in.); brecciated felstone, cemented with quartz.

This brings us to the third Kilbirnie dam, a beautifully clean one, and quite beyond the influence of civilisation. A yellowish sandstone, *in situ*, below the dam, is the only rock exposed in the bed of Garnock since we left old Dalgarvan dam. From this to the foot of Glen Garnock a great many boulders, all hill blocks belonging to the district, but no foreigners observed. A few may be noted :—Porphyrite with prehnite; amygdaloid with cavities filled with small red stilbites and calcite; porphyrites containing large cavities with yellow calcite, frequent; *two pebbles of milk-white vein-quartz (4in.)—of course foreigners; agglomerate with rounded (5in.) pebbles of porphyrite in a greenish paste; reddish boulder of porphyrite with redder crystals of felspar, and very hard; some felstones, dolerites, and anamasites. None of these boulders were over 5ft. diam.

Glen Garnock is for the most part bounded by perpendicular walls of porphyrite as far as the castle, rising in some parts to a considerable height, and has evidently been cut off *since* the glacial period, the old glen filled with Boulder-clay lying probably a short distance to the N.E. A fine-grained greenish dolerite dyke in glen, about 6ft. wide, cuts through amygdaloid with hollow cavities, and others filled with small red stilbites. A small greenish ash-bed is seen about the middle of the glen, and veins of barite, 2in. to 3in. wide, cut through the porphyrite a short distance below the castle. A little below and at the castle, in river bed, is an agglomerate *in situ*, with well-rounded *stones and boulders* up to 4ft.

diam. The paste is greenish, and the stones, where exposed, appear all porphyrite. It looks like an ancient Boulder-clay belonging to the period that intervened between the Calciferous sandstones and the base of the Carboniferous limestone, and deserves a visit from interested parties. From the castle to the falls the stream is nearly rock-bound all the way. Only at a few places does the glen open out for a small space, being for the greater part of the distance an old V-shaped glacier gutter. Patches of Boulder-clay are seen here and there lying on the slopes for a distance of 150ft. up. With few exceptions all the boulders are local, and no foreign blocks *or pebbles* were observed in any of the Boulder-clay exposures. The following were observed:—Small boulder with analcite; striæ on the rock in the direction of the glen, a little above castle. Some pieces of barite; *pebbles of vein-quartz, one mile above the castle; greenish ash-beds in the porphyrite; quartzite (12in.), resembling the rock at Muirshields barite mine.

One-and-a-quarter mile above the castle the rock is a soft amygdaloid with calcite-filled cavities containing a few red stilbites. At some places the river has cut below the old glaciated surface into the porphyrite for a distance of 10ft. to 20ft. At one part there is a fine *perpendicular* glaciated face of rock of 10ft., and in the direction of the glen. Another glaciated surface with striæ rather more to the westward. About two miles above the castle a *quartz pebble (1in.); *another further up (2in.). Quartz is getting precious. Large cavities in porphyrite lined with beautiful quartz crystals; amygdaloidal boulder (3ft. diam.); *magnesian limestone (8in. diam.) with numerous veins. There is no magnesian limestone *in situ* in the Garnock Valley. *Light fine-grained very tough greywacke (3ft. diam.), nearly globular; *small quartzite boulder with red jasper, the only one of its kind seen; *magnesian limestone (9in. diam.); *contorted schist (2ft. × 15in.), well rounded and very hard, not far from the mouth of the King's Burn. Thin red ash-bed opposite to where the burn comes in on the left. Rock at the 20ft. falls, reddish porphyrite; a little further up, greenish porphyrite with globular white blotches. A short distance above the 20ft. falls the stream runs in the line of a narrow white claystone dyke. *Two quartz pebbles (2in. and 3in.); soft white claystone dyke, 2ft. wide; agglomerate with 6in. pebbles. The second burn to the left runs in the line of a

thin dolerite dyke. *Quartzite (8in.). The stream here runs over a slanting fall of 15ft. *Quartz (3in.); a six-sided column of amamasite with pretty sharp angles (2ft. × 8in. diam.), in Boulder-clay; green dyke with pink felspar a little above the mouth of Murchan Burn.

The same dyke crosses Garnock and runs in the line of Murchan Burn for some distance—a beautiful rock. *Small boulder of white porphyrite showing flow-structure, laminated with red jasper and having red crystals of felspar, a very beautiful stone, and the only one of its kind observed. From this part to the large falls the glen is bounded by rocky walls. In some places the rock is purplish in colour with white blotches, from mere specks up to 9in. diam., some of them globular, others very irregular, and it is traversed by a few white claystone dykes. The scenery about the falls is quite highland, and spring flowers are here found blooming late into the summer. Above the falls the river runs through an open moor and so continues to its source in the Hill of Stake, which is 1711 feet high. A few fragments of Highland rocks were got to within 200 feet or so of the top of the hill. A short distance beyond the falls a few veins of hematite and barite are seen crossing the stream.

The Penny Burn joins Garnock estuary 3 miles from the sea. Opposite Todhills it flows over Boulder-clay, the stones in which are covered on top with *Melobesia polymorpha*. Some of the limestones have their upper surfaces all eaten into holes by marine animals, whilst the under surfaces are beautifully glaciated and fixed in the Till. A considerable number of the boulders are of white limestone belonging to the upper part of the Lower Carboniferous limestones. The rocks in this neighbourhood belong to the Upper Coal measures. There are a few boulders of small size:—*greywackes; sandstones; dolerites; and porphyrites; above Broom, grey dolerite *in situ*; *quartz (8in.); *greywacke (11in.); *grey Glenfalloch diorite (5in.). Above Kilwinning and Stevenston road at Castlehill are two conspicuous volcanic agglomerate rocks of Permian age rising to the west side of the burn like two small hills, both shewing very decided crag and tail. (Plate VIII., fig. X.) Further up are a few trap boulders up to 3ft. diam.

Red Burn joins Garnock at Dykehead. It gets its name from the peculiar burnt sienna colour it gives to everything over which it flows. This is caused by the iron compounds dissolved from the

Post-tertiary sands and gravels of the district. Where there is a very strong run many of the drains in this neighbourhood will only last for about four years before they require to be taken up and relaid. Nor does it matter how steep the drains may be laid. I have seen rhones that were placed *vertically* in a pit shank, where the flow of water must have been very rapid, completely choked with hydrated iron oxide. In the upper part of Redburn in Eglinton policies quartz pebbles are pretty frequent in the stratified sands, and near its source at Sourlie railway is a boulder of anamasite 3ft. in diam. lying imbedded in gravel, which must have been borne to this position—90ft. above sea-level—by floating ice. (Plate IX., fig. XIV.).

Lugton Water from Garnock to Lochlibo. Lugton Water joins the Garnock 1 mile below Kilwinning and 4 miles from the sea, at Dykehead, near where the large quantity of boulders are lying in the river's bed. I have said it appears that lots of boulders may indicate thick Boulder-clay, and the Boulder-clay sections seen above the level of both Garnock and Lugton at this part are rather thin, but that it has once been pretty thick is quite possible. We see at Corsehill that the old 25 feet sea-margin abuts against thick Boulder-clay, and no doubt the Boulder-clay to the south of Kilwinning has suffered greatly from marine denudation when the sea stood at that level.

Near the mouth of Lugton and up as far as Eglinton gardens are a good many boulders. One of the first we meet with, about 50 yards above the bridge, is a * grey granite (3ft. diam.), without large mackles. There are white veins through it projecting slightly on the surface. I suppose we are not now to consider these veins as of a subsequent and distinct formation to the granite, but to be the remains of the mother liquor in which the granite crystallized. Light green dolerite (5ft. × 4ft.); * grit with reddish quartz grains (4ft. × 3ft.); * green grit (2ft.6in. × 2ft. × 9in.); small crinoidal limestone (3ft.6in.); *several quartz pebbles (3in. to 4in.); *fine-grained grey grit (3ft.6in. × 3ft.); Beith blue limestone (5ft.); * sandstone conglomerate with white quartz pebbles 1in. diam. (3ft.); hard yellow sandstone (2ft.6in. × 2ft. × 15in.); another a little rustier. *A good many pieces of fine-grained greywacke in gravel near gardens; *grey granite without mackles opposite west garden wall (20in. × 15in. × 15in.); a lot of boulders of dolerites, anamasites, under 2ft.; small boulder of fine grey rhyolite; a lot of

small traps, &c., built into dambreasts and along side of stream at Eglinton Castle; *fine-grained grey grit (3ft.6in. × 3ft.3in.) *with edges very little worn*, near bridge above Tournament holm; hard grey sandstone (4ft. × 2ft.6in.); porphyrite with greenish felspar (3ft. × 3ft.); Beith limestone (3ft. × 2ft.6in. × 15in.), tabular; * vein-quartz (11in.); porphyrite, with white blotches, part of a "slaughtered" boulder; *fine-grained bluish grit (9in.); Fergushill Ha' dolerite (20in.); green ash (16in.); "white horse" (12in.); Fereneze porphyrite (9in.) with amygdaloids; *mica schist with much white vein-quartz (2ft. × 18in.), very irregularly striated; *grey grit (14in.); *red sandstone conglomerate with pebbles of white quartz and reddish, greyish, and brown felstone (6in.); *Ben Cruachan granite (18in. × 13in.) below Fergushill House; *yellowish white quartzite; *vein-quartz (9in.). Section of bluish Boulder-clay, 20ft. thick, above stream opposite Fergushill House, all the stones seen in it being small; *mica schist (4ft. × 3ft.), at dam near road; a lot of trap and limestone boulders opposite Saughtrees, all under 2ft.6in.; *fine-grained greenish grit (2ft. 6in.), flat; *greenish grit (9in.); *vein-quartz (3in.); small crinoid limestone (2ft.6in.); porphyrite (2ft.6in.); *vein-quartz (9in. and 6in.); many boulders at old dam, mostly dolerites; porphyrite with white blotches (18in.); *coarse-grained grey granite, no mackles (2ft.6in. diam.); *fine-grained grey grit (14in.); limestone (3ft.); reddish rock with agate (16in.); greyish-green porphyrite with yellowish-green felspar (4ft. × 2ft.6in.); *grey granite (18in.); near G. & S.-W. Ry. bridge; *fine-grained greywacke (16in.); limestone striated *across* (6ft. × 3ft. × 2ft.6in), a little above Snaker's bridge; limestone (3ft.); *vein-quartz (4in.); a good few boulders below Snaker's dam, mostly dolerites. Some intrusive dolerite here about position of Main coal and Raes-road coal.

From Sevenacres to Bullerholes there are not a great many boulders. The following are noteworthy:—Agglomerate, on side of Clonbeith railway, with pebbles of *Lithodendron* limestone; anamasite with hornblende (4ft.6in. × 3ft. × 2ft.); *greenish fine-grained grit (2ft.); Fereneze porphyrite (12in.); fine-grained greenish grit (4ft.6in.), opposite Montgreenan Cottage. A few boulders in stream opposite Clonbeith; and at this part of stream are large flat slabs of extremely hard sandstone, with what appear to be the remains of seaweeds twining in every direction and standing out from the surface in bold relief. Greyish-green por-

phyrite (4ft. × 2ft.6in.); *granite with reddish felspar (2ft. × 18in.), opposite Clonbeith pit; *grey grit with quartz pebbles up to 6 in. (8in.); *white quartzite with quartz veins (9in.); fine example of Fereneze porphyrite (3ft.) below little pond in policies; *vein-quartz (9in.).

From Bullerholes to Auchentiber the boulders, which are not many, are mostly dolerites with a few limestones and still fewer porphyrites. A greyish variety of Fergushill Ha' dolerite containing analcite, cluthalite, marcasite (9in.), &c.; clayband ironstone (9in.); *a few small grey grits opposite Megswells. Here the Clonbeith limestone crops out at side of stream, and is penetrated by small water-worn fissures—caves in embryo; *grey grit (2ft.6in. × 10in.); *Ben Cruachan granite with 2in. felspar mackles (20in.), at Redwells ford; *coarse grey grit (2ft.); and a few smaller ones; *very fine-grained blue slaty grit (11in.); greenish mass of *Lithodendron fasciculatum* (18in. × 4in.); and a smaller one; *grey grit with some milky quartz (20in.); *green* sandstone (16in.); *blue slaty grit with glassy quartz (14in. × 4in.); limestone (4ft. × 3ft. × 1ft.6in.); *Old Red Sandstone (6in.).

Near Redwells ford bluish Boulder-clay is 15ft. thick above stream; a few small grits between here and Auchentiber; a good few boulders from here up to Waterland bridge, mostly dolerites, but a few limestones and fewer sandstones. The following may be noted:—Dolerite (4ft. × 2ft.6in.; *mica schist (14in.), flat; Fereneze porphyrite (16in.); crinoid limestone (3ft.); crinoid limestone (5ft.6in.), square, tabular; *fine-grained greywacke opposite Thorn (16in.); Beith white limestone (6ft.); *felspar rock, rare (8in.).

At Lugtonridge small quartz pebbles are more numerous than elsewhere in Garnock Valley except on the seashore; *pink quartzite (8in); dolerite opposite Mantrap (4ft. × 3ft.); *grey grit with mica (14in.); **white* grit with glassy quartz (10in.); a lot of dolerites built alongside stream opposite Mantrap; *greenish fine-grained quartzite (10in.); *very fine-grained greywacke (8in.); *mica schist (6in.); Fereneze porphyrite (4ft. × 3ft.); laterite *in situ* in bed of stream opposite Oldhall; crinoid limestone (3ft.6in. × 2ft.); amygdaloidal porphyrite (14in.); *pink quartzite (5in.); *fine-grained green greywacke (10in.); *fine-grained green greywacke with $\frac{1}{8}$in. glassy quartz (18in.); Fereneze porphyrite (7in.); *quartz (7in.); *greywacke with $\frac{1}{8}$in. glassy quartz (14in. and 16in.); *vein-quartz

(8in.); grey porphyrite (14in.); a few small greywackes (6in. to 10in.); *grey quartzite with quartz veins (7in.); *grey grit, with white quartz and a little red jasper up to $\frac{5}{8}$in., (10in.); *reddish hornblendic felsite (12in.), near Gree; two Fereneze porphyrites (12in.); *fine-grained green greywacke (14in.); Wee Craig dolerite (7ft. × 4ft.6in.); greenstone *in situ*, with a little felspar, a little below Old Mill; *fine-grained greywacke (10in.); *greywacke with $\frac{3}{8}$in. quartz (20in.); a few smaller ones with finer grains. A 12ft. section of Boulder-clay seen below Beith railway, in which the stones are all small.

We may here vary the record by noting a fine patch of *Sedum acre* in flower, and a little further up another of Monkshood. Fereneze porphyrite (13in.); anamasite dyke, 24 yards wide, at old houses above railway bridge; *grey grit (5ft. × 3ft.9in. × 2ft.) with $\frac{1}{2}$in. quartz pebbles lying on dyke; *grey grit with quartz veins (18in.); *fine-grained greywacke with fine muscovite (13in.); *grey grit with $\frac{1}{4}$in. quartz pebbles (18in.); *grey grit with minute glassy quartz (11in.); *contorted schist (12in.). This brings us to Waterland, where a cutting has been made through rock to drain the loch, of which Lochlibo is the remnant.

Draff Burn joins the Lugton in Eglinton policies. In its course through them not many boulders are to be seen, and all under 2ft. 6in. By Lord Eglinton's instructions the Kingfisher is protected here, and I had the pleasure of seeing one when going along this burn, but woe to the unfortunate Halcyon that ventures out of this sanctum. On leaving the policies there are a few boulders before coming to Sourlie railway:—*Grey grit (16in.); kingle (13in.); dolerite (5ft.4in. × 3ft.10in.); a few smaller, up to 2ft.6in. diam.; *coarse-grained grey grit, only partly seen, at least 8ft. across, about 40 yards above road, the largest of its kind seen, and the largest foreigner in the Garnock Valley; prehnite (5in.); *red sandstone conglomerate (15in.), with quartz pebbles; a few sandstones and some small greenish greywackes; *quartz (6in.); a good few traps between railways. Above G. & S.-W. Ry. few boulders, and these small. Fereneze porphyrites (6in.); a few small grits; ****white*** grit (10in.).

Bensley Burn joins the Lugton in upper part of Eglinton policies. No boulders as far as wall. Above, blue limestone weathered into hollows (5ft. × 5ft. × 1ft.9in.); a few small boulders between wall and Doura railway; *quartz pebbles frequent; very few and small boulders between Doura and G. & S.-W. Ry.

Fergushill Burn. Very few boulders in this burn. *Some small grey grits.

Blae Loch Burn joins the Lugton near Mantrap. Not many boulders to be seen along its course; above the road a few traps. The following foreigners were noted :—*Greywacke with $\frac{1}{16}$in. glassy quartz (12in.); *greywacke with $\frac{1}{8}$in. glassy quartz and some milky quartz (18in.); *fine-grained greywacke (2ft.); *vein-quartz (11in.); *greywacke (16in.); thin veins of satin spar, opposite Burnhouse; *quartz (4in.); **white* quartzite (8in.), veined with quartz; *fine-grained greywacke near Beith railway (14in.); *Glenfalloch diorite at Dustyridges (16in.); *fine-grained greywacke (2ft.2in.) at Old Mill; a deep cut made through limestone to partly drain the rock-bound Blae Loch.

Redstone Burn joins Garnock at Kilwinning. In lower part of burn numbers of dolerites, anamasites, and some limestones, up to 3ft. diam.; *some quartz pebbles, up to 4in.; built alongside the burn some West Doura conglomerates, but these not properly boulders. This conglomerate, which is composed of beautifully almond-shaped white quartz pebbles has been largely used in the older part of Kilwinning Abbey, and from thence has found its way into many of the buildings about Kilwinning. I have never found any of this conglomerate as boulders, but this is easily accounted for, as the ground to the S.W. of West Doura, where it crops out, is covered with Post-tertiary beds. As the ice moved in this direction at this part of the valley there is not much likelihood of any being found except in the trifling area exposed by the Penny Burn. A few boulders opposite Bannock :—*Red* kingle (15in.); *some quartz and a few small greywackes; about this part some large drums of Boulder-clay, as Corsehill muir plantation, Bannock, &c.; *actinolite with very large crystals (5in.), the only one of its kind seen; Fereneze porphyrite (5in.).

Goldcraig Burn enters Garnock at head of Kilwinning dam, and in dry weather the water is remarkably clear, owing apparently to the large quantity of lime it holds in solution. It is a small stream; near its mouth the Boulder-clay is about 30ft. thick above stream, the burn here running on it. Not a great many boulders are to be seen, but the following were noted :—Wee Craig dolerites (4ft. × 3ft.); another (3ft.6in. diam.); and one (4ft.6in. diam.), near Dalry old road; white limestone (4ft.6in.), flat; porphyrite with white felspar patches (3ft. diam.) above railway; sandstone below

Clonbeith limestone *in situ* at Golderaig; greenstone (3ft × 2ft.6in.); *grey grit with ½in. glassy quartz (20in.); Beith blue limestone (2ft.), tabular; Clonbeith limestone (3ft.3in. × 2ft.3in.); Beith blue limestone (2ft.9in. × 2ft.6in.); *fine-grained grey granite (22in. × 10in. × 10in.) in dyke at Monkredding; red felspar porphyry; *grey grit (18in.); *fine-grained greywacke (7in.).

Rough Burn joins Garnock near Woodgreen farm, and thence to Dalry old road there are a good few boulders, mostly dolerites; limestone (4ft.6in. × 2ft.6in.); *quartz (9in.); *mica schist (8in.); *fine-grained grey granite (18in.); *grey grit with ½in. quartz (5ft. × 2ft.6in.); greenstone (3ft.); another (5ft. × 3ft.6in.); irony sandstone (5ft. × 2ft.3in.); *Ben Cruachan granite (21in. × 18in. × 16in.), about 50 yards below Dalry old road; section of Boulder-clay here 24ft., bottom not seen: Clonbeith limestone (4ft.6in. × 3ft.6in.); purple porphyrite (14in.); not many boulders from Dalry old road to railway; kingle (2ft.); porphyrite with white blotches (2ft.6in.); dolerite (3ft.); a few others about same size. A good few boulders from Flemland to opposite Jameston, mostly dolerites, and a few limestones. At Flemland the burn is carried under a deep cutting in the G. & S.-W. Ry. by three inverted siphons. *Grey grit with amethyst and opaline quartz (8in.); white sandstone *in situ* opposite mound: *grey grit with ¼in. quartz (8in.); *grey grit with glassy quartz and a little pyrite; yellowish angular kingle (15in.); *red sandstone conglomerate with 1in. pebbles of quartz (6in.); red felstone (9in.); *mica schist (7in.); section of Boulder-clay, opposite Jameston, 16ft., with some boulders (20in.); Beith blue limestone (2ft.8in. × 2ft.); anamasite (3ft.); a few quartz pebbles.

Auchenskeith Burn joins the Garnock at Groatholm. Here there is a wide depression in the general physiography of the district, owing to the soft ash-beds below the lower limestones having been scooped out by the ice-sheet. At a first glance it looks as if this depression had been cut out by the Garnock, but this is untenable, as the Boulder-clay slopes gently down into the river which has subsequently modified it by partly *filling in* some alluvial deposits. For the first half-mile on leaving the Garnock the burn flows over these deposits, and of course there are no boulders. Opposite Cockenzie are:—*Contorted mica schist (21in.), fragment: *pink quartzite (8in.); *greenish greywacke (14in.); a good few boulders above the Dalry old road; a few

quartz pebbles. In dyke at railway is a dressed block of Ailsa Craig syenite, which has not been cut from a boulder, but is one of those used as sleepers when the railway was first made. These blocks will no doubt puzzle the geologists and archæologists of the future, having been brought from various parts of the country, and being composed of various rocks, including granite. They are easily known by having two holes bored in them for the purpose of fastening the chair which held the rail. *Well-rounded grey Glenfalloch diorite (12in. × 11in. × 4½in.) opposite Auchenskeith; greenstone (4ft.6in. × 3ft.6in.); some white limestones, not much worn, a few 3ft. diam.; some dolerites and anamasites up to 3ft. diam., opposite Jameston; greenstone (2ft.10in. × 2ft.3in.).

Smithstone Burn joins Garnock near G. & S.-W. Ry. bridge and is a very small stream. We note near Dalry road:—Well-rounded limestone block (6ft. diam.); another rounded Beith blue limestone (8ft. × 6ft.); sub-angular blue limestone (6ft. × 3ft.6in. × 2ft.6in.); other smaller limestones, evidently from the outcrop near mouth of stream; also a few dolerites and anamasites.

Cartle Burn joins Garnock near Cartleburn farm. South of stream and a little above Dalry road the Lower Carboniferous limestone has been mined. On top of old mine is seen a section of both the ground moraine and iceberg Boulder-clays with stratified sand-beds between, the only place in the Garnock Valley where the iceberg Boulder-clay is to be seen. The section is as follows (Plate VIII., fig. IX.):—

Reddish granular quasi-stratified iceberg Boulder-clay, with boulders up to 22in. diam., . .	8 ft.
Yellowish and grey sand with thin layers of clay and coal partings, ...	9½ „
Tough reddish blue Boulder-clay (ground moraine),	4½ „

In the interstratified sand I have not been able to detect a vestige of even a microscopic organism. Opposite the old kiln there is a Blair greenstone (4ft.3in. × 3ft.6in.); limestone (5ft. × 4ft.6in.). A bit of Bavarian lithographic stone was got here, but some green coloured inverted lettering on it prevented us from speculating on the probability of a special small iceberg post having brought it over. A few dolerites and some limestones at upper old quarry; *grey grit with ⅛in. glassy quartz (20in.); *another with ¼in. glassy quartz (9in.), near Gateside.

Dusk Water enters the Garnock at head of Dalgarvan dam. Near

its mouth is a grey chert (unfossiliferous to the naked eye), (21in. × 14in. × 9in.), rounded a little at the corners, minutely spotted with white all through the mass, the spots changing to red where decomposition has set in; the parent rock is not known to me. A few traps and limestones are seen from the Garnock to railway bridge. A short distance above railway bridge Boulder-clay is 30ft. thick, and occupies bed of stream. For 100 yards up boulders are numerous:—Many dolerites and anamasites, some over 4ft. diam.; limestones and a few sandstones; *fine-grained grey grit; grey porphyrite (2ft. × 14in.); sandstones (4ft. × 2ft.); porphyrite with quartz (15in.); *vein-quartz with sooty cavities (7in.); kingle, well-rounded (8in.); grey porphyrite (2ft.6in.); *grey actinolite rock (8in.), the only one of its kind seen; *a few quartz pebbles and small grits; *grey grit with ½in. quartz (15in.); below Kilmarnock railway bridge some deposits of mahogany-coloured clay, a rewash from Boulder-clay; small pot-holes in clay in bed of stream; two limestones (3ft.3in. diam.); many dolerites and anamasites; a few limestones and sandstones from railway to Dalry old road; reddish-brown felstone (2ft.8in. × 2ft.); a great number of dolerites from road to Waterside dam, many over 3ft. diam.; tabular limestone (5ft.6in. × 2ft.6in. × 2ft.); porphyrite with red felspar (3ft.6in. diam.); bluish porphyritic dolerite (6ft. × 3ft.6in.); amygdaloid with egg-shaped cavities in grey paste (20in.), at Waterside, a unique variety. The rock emerges here from under Boulder-clay in the shape of ash-beds. Beith blue limestone (20in.); limestone, tabular (3ft. square); *greywacke (2ft.); *another (20in. × 18in. × 7in.); fine-grained greywacke with a little mica, at dam, and lot of small boulders; agglomerate with rolled pebbles (18in.), a unique variety; *vein-quartz (6in.); reddish-brown felstone porphyry (3ft. diam.); grey porphyrite (6ft. × 2ft.9in. × 2ft.9in.) with pitted surface, at Auchenskeith ford, long axis in direction of ice-movement; green porphyrite (4ft.6in. × 3ft.3in.); reddish-brown porphyrite (6ft. × 4ft.6in. × 3ft.6in.); green dolerite dyke with a little felspar, and slightly amygdaloidal in parts, 25 yds. wide, in Cleaves glen; grey agglomerate (3ft.6in. × 2ft.6in. × 2ft.), where red and green ash-beds crop out in glen; bluish-grey porphyrite (2ft. × 20in. × 20in.); *fine-grained greywacke (2ft.6in. × 20in.); red felstone (4ft. × 3ft.); anamasite (4ft. × 2ft.6in.); very few boulders where limestone comes near the surface at Cleaves Cove; one or two dolerites between first and second falls in Cleaves glen.

From here to Blair mill only a few small dolerites and felstones; a few dolerites and anamasites from Blair mill to Ravenscraig, some over 3ft. diam.; *fine-grained greywacke at dambreast (2ft.6in.); grey ash-beds, with hard green nodules, below Ravenscraig quarry; grey sandstone (6ft. × 5ft. × 3ft.), angles a little rounded; shaly limestone (6ft. × 6ft. × 3ft.) *Scrophularia Ehrbarti* is a common plant from here up. Very few boulders from Ravenscraig up to old dam; *Ben Cruachan granite at old dam (18in. diam.); stream becomes sluggish here, and for a considerable distance is filled with *Equisetum limosum*. Opposite Pencot limestone shales on edge; grey sandstone (6ft. × 4ft.), with sharp angles; *green* limestone (18in.) below Auchenmade kilns; very green (4in.) intrusive beds of dolerite resting on ash *in situ*; lower limestone *in situ* in bed of stream below Dalry road; *greywacke (3ft.); *pink quartzite (3in.); *chlorite schist (3in.); *greywacke with $\frac{1}{16}$in. to $\frac{1}{8}$in. glassy quartz (5ft. × 3ft.6in. × 2ft.6in.), 50 yds. below Auchenmade bridge. From here to Waterside farm stream is sluggish, with few boulders; some small ones a little below Giffen House; a few boulders between road and Barmill railway; grey porphyrite (3ft.6in. × 3ft.) above railway; thin seam of clayband ironstone seen dipping west at Girleston.

No boulders from this to Barmill; stream flowing through a narrow alluvial meadow with many yellow water-lilies. A leaf measured 13½in. × 10½in. with 4½in. cleft, and I note for first time that leaves growing entirely under water are very much crimped, in the manner of a green-kale blade. Above Barmill strata dip steeply. Not many boulders to Hesselhead, mostly dolerites and anamasites, with a few porphyrites. The following may be noted:— *Mica schist (4ft. × 2ft.6in.), below Barmill dam; brown angular kingle (3ft.6in. × 1ft.8in. × 1ft.8in.); *contorted mica schist (14in.); *fine-grained greywacke with quartz veins (2ft.6in. × 1ft.8in.), 6 feet deep in Boulder-clay; *Old Red Sandstone (2in.); near road the strata on edge; dolerite with green glassy crystals (4ft. × 3ft.6in.); *grey grit (9in.); bluish porphyrite (4ft.6in. × 3ft.6in.); another (4ft.6in. × 3ft.); *grey granite in dyke near stream (23in. × 14in.), 200 yds. south of Hesselhead; dolerite with minute saponite (14in.); *grey granite (18in. × 14in.), opposite Hesselhead garden; Hesselhead bridge built on anamasite dyke; *mica quartzite (6in.); *greywacke with $\frac{1}{16}$in. glassy quartz (14in.); *mica schist (12in.); *brown sandstone conglomerate with 1in. pebbles of quartz

(13in.): lot of limestones with *Lithodendron fasciculatum*; crinoid limestone (4ft.6in. × 3ft.), flat: cutting through anamasite to drain small rock-bound loch at Washingstane: *mica schist (17in.): *a few quartz pebbles up to 3in.: *contorted schist (6in.): *mica schist (6in.).

This brings us to Coldstream, where is found the parent rock of the Wee Craig boulders. *Green greywacke (18in.): *vein-quartz (9in.); stone in clay pot-hole in bed of stream (5in. diam.): *greywacke with $\frac{1}{16}$in. glassy quartz (18in.): *quartz (9in.): *contorted mica schist (10in.): *grey granite in dyke near Townend: *greywacke (18in.): *two greywackes with $\frac{1}{16}$in. glassy quartz (20in.): *grey granite in dyke with 1in. projecting fins (22in. × 13in. × 8in.): *contorted schist (13in.): *fine-grained greywacke (20in.): *grey grit with $\frac{1}{8}$in. quartz (13in.): *a few quartz pebbles opposite Rigfoot: several small Fereneze porphyrites; *quartz and hornblende (18in. × 16in.), very hard and well-rounded, the only one of its kind seen; boulders of Fereneze porphyrite frequent. A little beyond Rigfoot we reach the home of the Fereneze and Lochliboside hills porphyrite, which is easily known, wherever found, by the abundant large crystals of Labrador felspar it contains.

Monkcastle Burn, which joins Garnock about a mile above Dalgarvan, is a small stream with few boulders. The following were noted:—Yellow sandstone (3ft.8in. × 3ft.); anamasite dyke, 6ft. wide; bridge at Dalry road built on one of the upper limestones: greenstones (4ft.6in. × 2ft.6in.), flat; (4ft.6in. × 3ft.6in. × 2ft.6in.); (3ft.8in. × 3ft.6in. × 3ft.): dolerite dyke in glen, 4ft. wide, amygdaloidal in centre. The glen here ends in a *cul de sac*, with 10ft. of ash-beds supporting 30ft. of dolerite, over which the burn falls. Above the falls are:—*Fine-grained greywacke (9in.): Kamehill conglomerate (9in.).

Bombo Burn joins Garnock a little below Kilkush. From the mouth up to where the Blair dolerite is seen *in situ* there are quite a lot of boulders, mostly dolerites. The following may be noted:—Wee Craig rock (4ft. diam.), between railways; upper limestone (6ft.6in.): greenstone (3ft.6in. × 2ft.6in. × 2ft.): dolerite (4ft.6in. × 3ft.); *pink quartzite with some $\frac{1}{8}$in. milky quartz (3ft.6in. × 2ft.6in.), a fine block, and by far the largest of the kind in the Garnock Valley; irony sandstone (5ft.); *vein-quartz (4in.); *greywacke with $\frac{1}{4}$in. glassy quartz; grey sandstone, tabular (7ft. × 7ft.3in.); bluish porphyrite (7ft. × 5ft.). We here note a

fine patch of the rare *Sedum reflexum* on the side of stream, and on the wall close by, *Asplenium ruta-muraria*. Upper limestone (4ft.3in. × 3ft. × 3ft.); another (6ft.6in.); another (8ft.1in.); Beith blue limestone (1ft.6in.); grey sandstone, tabular (6ft.6in.); shaly blue limestone, tabular (3ft.); grey sandstone, tabular (4ft.); another (9ft.6in.); in wall close by stream *two Ben Cruachan granites (11in. and 14in. diam.); *grey grit (12in.); Carboniferous chert (9in.); *white felspar rock (6in.), the second of its kind seen; *grey grit ($\frac{1}{8}$in.); quartz (14in.).

At Blair rockery we notice some specimens of fossil plants. One very fine *Lepidodendron* (2ft. diam.) shows the remarkable quadripartite forking of the base, the four principal roots being each forked at 10in. and 12$\frac{1}{2}$in. from base of stem. The dolerite here is pillared and very decomposable. Dolerite (4ft. diam.); small dolerite with specks of red saponite; grey *micaceous* fossiliferous limestone, tabular (6ft.); upper limestone (9ft.), flat; grey micaceous limestone (6ft.); grey micaceous limestone in position near gamekeeper's house; upper limestone (5ft.4in.); second upper limestone *in situ* at gamekeeper's house; a good many boulders in Blair policies built along the sides of stream; most probably brought from fields, as the Boulder-clay is thin here. At Lambridden quarry, where the upper Carboniferous limestone has been wrought, *pink quartzite; *quartz with red jasper (8in.).

From Bombo falls to source of stream at south-east of Beith not many boulders, but the following were noted:—*Ben Cruachan granite near branch railway (12in.); laterite (6in.); Wheatyfauld greenstone (3ft.3in.); near Giffen road, dolerite (2ft.3in.); *a few quartz pebbles (3in. to 4in.); *grit with glassy quartz (5in.); *gneiss (2$\frac{1}{2}$in.), the only one of its kind observed. *Nasturtium officinale* very common where stream is sluggish. Miocene anamasite trap dyke at Barhill road, bluish and fine-grained, with finer patches. It is largely quarried at Barmill and at Giffen old castle, and is the probable source of many of the boulders of the Garnock Valley. As the Bombo is a self-contained stream with no lateral branches we pass on to Caaf Water.

Caaf Water enters Garnock a mile below Dalry. There are not many boulders from the mouth to Linn Spout, and for 100 yards below Spout scarcely any. Have they been pounded into mud, sand and gravel, as the falls retreated, for these appear to have cut their way back about 106 yards since the glacial epoch? Kamehill con-

glomerate (14in.); small coarse-grained grit with ½in. quartz pebbles; *purple sandstone; fine boulder of porphyrite near mill-wheel at Linn Spout. The Spout is 35ft. high, and is formed of the upper limestone, which is here very thick and in parts very fossiliferous. A short distance above falls some large blocks of millstone grit have fallen from the cliffs above, one measuring 23ft. × 18ft. × 12ft. This sandstone appears to be very durable, and anyone who wishes to build cyclopean walls will find the material here. A little below Drumcastle bluish Boulder-clay is 30ft. thick, resting on the rock 10ft. above the stream. The boulders are mostly dolerites, porphyrites, and limestones. *Hornstone (4in.); porphyrite (6ft. × 4ft. × 3ft.6in.); and *fine-grained greywacke (4ft. × 3ft. × 2ft.6in.); both resting on sandstone in bed of stream. Proceeding along by the alluvial holms of Caaf not many boulders met with till Giffertland is reached. Numerous pebbles of Kamehill conglomerate; blasted porphyrite with greenish felspar, at mouth of Auldmuir Burn; Howrat white limestone (2ft.6in. × 2ft. × 18in.); *vein-quartz (12in. × 7in. × 5in.); some large porphyrite blocks at Giffertland plantation; porphyrite with glassy felspar (7ft. × 5ft.); red porphyrite (2ft.); *quartzite (2in.).

Above Giffertland plantation is a thick deposit of volcanic ash with large crystals of biotite. In it Mr. Edward Carrick, Dalry, detected *Productus* in fragmentary condition. It also contains quartzite pebbles, charred wood, and *well-rounded* limestone pebbles with crinoid remains. To return to the boulders:—Kingle (5ft. × 2ft. × 18in.); porphyrite (12ft. × 9ft.); *contorted schist (10in.); porphyrite (12ft. × 8ft.), 400 yards below Giffertland mill; *contorted schist (12in.); 20ft. of Boulder-clay with frequent limestone blocks opposite Blackstone; Howrat limestone (3ft. × 2ft.6in. × 12in.); *quartz (4in.); Carboniferous limestone pebble, 300 yards below Birkhead glen, the last limestone seen going up stream; quartzite (9in.), with white quartz and red patches; Kamehill conglomerate (2ft.6in.); *fine-grained greywacke (2ft. × 13in.); contorted schist; greywacke (7ft. × 5ft.), opposite old kiln. This is the second largest foreigner seen, and this variety of rock is known in the district by the expressive and correct name of "Hielan' whin," also "Devils tae breck." The upper white part of lower Carboniferous limestone has been worked here. Red porphyrite (18in.); *contorted schist (2ft. × 2ft. × 18in.), above first glen; *fine-grained greywacke (6in.); *mica schists (3in. and

9in.); gritty schist (7in.); irony sandstone with *red* quartz pebbles, *parts* of some of the pebbles being white. Boulder-clay above Birkhead glen is 40ft. thick, and of a reddish-brown colour. The Calciferous sandstones further up the glen are now beginning to tell on the colour of the Boulder-clay. The hill porphyrite is first seen *in situ* in Birkhead glen. Porphyrite (7ft.6in. × 6ft. × 3ft.); Kamehill conglomerate (4ft. × 3ft. × 2ft.6in.); near mouth of Drum Burn 20ft. of reddish-brown Boulder-clay; grey porphyrite (6ft. × 6ft.), at mouth of Drum Burn.

From Birkhead to source of the Caaf in Lairdside hill no foreign blocks were noted, but the following local ones may be mentioned:—A lot of small porphyrites and felstones in bed of stream above Birketsteel bridge; the Boulder-clay is 40ft. thick and of reddish-brown colour, and opposite Wardlaw it is the same thickness. Large blocks of Kamehill conglomerate between Brodshaw and Wardlaw. It must be mentioned that this conglomerate, though not so thick as at Kamehill, crops out on opposite side of Caaf valley. Porphyrite (9ft. × 6ft. × 5ft.); reddish Boulder-clay, 20ft. thick, opposite Brodshaw. Here are to be seen sun-cracks, 7in. diam., in Calciferous sandstone.

The *Brodshaw Burn* branches to the east, and in it is seen a good section of part of the Calciferous sandstone series, and the junction with the porphyrites above it. In the Kamehill conglomerate, which has been long used for millstones, the pebbles are nearly all of beautiful white quartz up to 3in. diam. There are also a few light-pink-coloured quartzites. We now come to Lairdside hill, where the Caaf has its source. This hill is of dolerite, has a steep face to the north-west, and a long gentle slope to the south-east, 15° magnetic.

Munnock Burn runs into the Caaf at Drumcastle dam; *Old Red conglomerate. Not many boulders till Caddle is reached, where there are a number of dolerites and porphyrites:—*mica schist (18in.); *red* kingle (8in.); *grit (9in.); *two mica schists (10in. and 11in.); Kamehill conglomerate (21in.); at Munnock dam are a lot of small *greywackes; two porphyrites with agate; *quartz (6in.); *contorted mica schist (3in.); *vein-quartz with mica (7in. and 13in.); *fine-grained greywacke and contorted schist (7in.); at Munnock 1in. vein of barite *in situ* in purple ash; purple Calciferous sandstone dipping E.; Kamehill conglomerate (20in.); a quarter of a mile below Gill farm Calciferous sandstone dips

S.E. at 40°. Near Gill farm some Kamehill boulders (12in.): porphyrite (4ft.6in. × 3ft. × 2ft.); and near source a Kamehill (15in.).

Auldmuir Burn joins Caaf at Giffertland. Not many boulders are seen in its course, but some porphyrites near lower part. The following were noted:—Porphyrite (8ft. diam.): strata on edge and over it at Giffertland: porphyrite (7in. diam.): Kamehill conglomerate (20in.): red and green ash-beds and agglomerate below Auldmuir: above Auldmuir black shale dipping S. at 40°: *red jasper (4in.), the only one of its kind seen: *some vein-quartz (2in. to 4in.), part of which may be from Kamehill conglomerate.

Drum Burn joins Caaf a quarter of a mile below Birketsteel bridge: not many boulders to be seen in it: greenish porphyrite (7ft. × 5ft. × 4ft.); *contorted schist near small waterfall opposite Birket: porphyrite (5ft.): two large Kamehill conglomerates, only partly seen: another opposite Knockendon (4ft. × 2ft.4in.); sandstone *in situ* with quartz pebbles and thin vein of crystallised barite: burn running on reddish Boulder-clay opposite Knockendon. Kamehill conglomerate (5ft. × 4ft. × 3ft.): mass of sandstone, 15ft. long, possibly not a boulder, with two sets of striæ on upper face and nearly at right angles to one another, but neither of them in long direction of stone: laterite *in situ* in bed of stream: amygdaloidal porphyrite (3ft.): porphyrite (4ft.); reddish Boulder-clay, 20ft. thick. To west of burn near its source is a great hollow, like an amphitheatre, scooped out of the side of Caldron hill, and probably the work of ice.

Drumside Burn joins Drum Burn half-a-mile from its mouth. *Contorted greywacke (5ft. × 5ft.); *greywacke (18in.): quite a lot of Kamehill conglomerates on hillside near source.

Potyan Burn joins Garnock near south end of Dalry. Not many boulders observed along this small stream, and those for the most part local. At Brodlie bluish Boulder-clay, 7ft. thick: *greenish grit (8in.); small boulder of grey mica trap (?): some small sandstone boulders at Fleshwood.

Rye Water joins Garnock half-a-mile N.E. of Dalry. A few quartz pebbles below Stock bridge. Few boulders seen till Drakemyre:—red porphyrite pebble opposite Bogs (5in.); at Drakemyre a few local boulders, over 3ft. diam. From Drakemyre to Camphill boulders are numerous, which would seem to indicate that Rye glen had been pretty well filled up with Boulder-clay, the greater

part of which has been washed away:—round porphyrite above Dogertland (5ft. diam.); *grit at Ryefield old mill ruins (4in.). Small block of *Lithodendron junceum* in bed of stream; sides worn smooth, but corallites projecting $\frac{1}{8}$in. above surface, which would seem to indicate that sand and gravel carried down by water act as abrading agents only at and near the sides of limestone boulders, whilst acids in the water act on all exposed surfaces. Large flat piece of blackband ironstone; *quartz (2in.); all the quartz pebbles in Rye are likely to be foreigners; porphyrite boulder with prehnite; porphyrite boulder with quartz crystal in cavity; porphyrite boulder with chalcedony, stilbite, and quartz crystals; porphyrite boulder with agate; Dalry blackband ironstone cropping out in Hindog glen; *quartz (3in.); porphyrite with chalcedony; kingle (5in.).

No sandstone boulders seen in Rye Water above Hindog; from Hindog glen up to the source the rocks all belong to porphyrite series; clayband ironstone boulders above Cunningham Baidland footbridge. The section in glen near this will be found described by the late R. A. Skipsey, in *Transactions*, vol. ii., page 248. Where the glen is steep and rock-bound there are no boulders. They seem to have been carried down by floods, and left at the nearest open parts. *Chlorite schist (5in.); Boulder-clay, 50ft. thick, with many limestone blocks; limestone (5ft. × 2ft.6in.); another (2ft. 6in.); another (7ft. × 3ft.); Boulder-clay, 40ft. thick, opposite Greenhill; limestone (2ft. diam.); limestone (5ft. × 3ft.) with *pebbles* of amygdaloid and felstone, opposite Howrat. This block is probably from the outcrop N.W. of Auchenbon, and would seem to indicate that when the lower Carboniferous limestone was being deposited part of the hills to the north were above or near sea-level. I do not know of any other instance of hill pebbles having been got in this limestone. Below Haining, part of river gravel converted into conglomerate; barite (3in.); *well-rounded grey quartzite (20in.); numerous large boulders of porphyrite; *Lithodendron* limestone (18in.), the last limestone boulder met with in the Rye Water; a section of the Boulder-clay below Haining, 30ft. thick, with boulder near the top (4ft. diam.); all the rest small; *quartz (3in.); brownish Boulder-clay at Camphill, 30ft. From Largs road to source of the Rye in Irish Law very few boulders; glaciated surface below Howcraig in line of glen, which is narrow here; *three quartz pebbles (2in. and 3in.); basalt

(18in.); Boulder-clay near junction with small stream, 20ft. thick; above this stream runs over reddish porphyrite, with agglomerate and felstone near the source.

South Burn joins Rye 1½ miles above Cunningham Baidland, and its whole course is over the hill porphyrites, with here and there Boulder-clay for its bed. Few boulders in it, and all hill blocks. No foreigners observed, not even a quartz pebble. Near road a cavity in porphyrite *in situ*, containing beautifully clear crystallised barite; two red porphyrites (20in.); Boulder-clay on north side, 30ft.; on rock opposite Plann, 15ft.; reddish porphyrite (8in.); striæ, 18° S.W. (mag.), near source.

North Burn joins the Rye opposite Howrat castle hill. Boulders not numerous, no foreign ones observed but one *quartz pebble. Near mouth grey porphyrite seen *in situ*. Dark porphyrite (4ft.6in. × 4ft. × 3ft.); red-bedded porphyrite dipping up stream at about 45°, above and below water catch. *Quartz (1in.); Boulder-clay, 20ft, ½-mile above Haining, stones in it all small; red porphyrite (16in.); bluish porphyrite with green felspar (9ft. × 5ft.); two others a little smaller; Boulder-clay, 30ft., stones all small; red porphyrite (17in.); Boulder-clay, 24ft., stones small; Boulder-clay, 20ft., stones small; Boulder-clay, 30ft., with porphyrite (4ft. × 3ft.) at 6ft. above burn; porphyrite with agate (3ft. × 1ft.6in.); striæ N.W. to S.E.; grey-blotched porphyrite (6ft. × 6ft. × 5ft.6in.) at irony spring, side of stream; several irony springs in bed of stream; bluish porphyrite with greenish felspar *in situ* at Blae Loch; good many boulders in North Burn, few towards source; all the Boulder-clay on north side of stream, the reason appearing to be that the burn began at tail end of Boulder-clay and is working its way northwards.

Routen Burn.—The *Rout dane* Burn joins the Rye near to Camphill. At Largs road greyish porphyrite, with little felspar and a few patches of green saponite, *in situ*, weathering to a purplish colour; some agglomerate boulders composed of fragments of red felspar porphyry; *quartzite (3in.); *quartz (3in.); *mica schist (1½in.)—all a little above Largs road; *quartz (1in.); *honey-coloured hornstone (4in.); *mica schist (5in.); boulders of reddish porphyrite frequent; *three quartz pebbles (2in. to 3in.); barite (3in.); green ash *in situ*, with veins of calcite, some solid and red; *greenish quartzite (3in.); *quartz (4in.); *greywacke (4in.). Where the bed is steep and rocky the Boulder-clay is only 5ft. or

6ft. thick, and 20ft. to 30ft. above stream; where the gradient flattens the Boulder-clay is 12ft. thick. Barite (3in.); *quartz (4in.); finely-striated surface in bed of stream, striæ pointing to valley; *coarse-grained grit (12in.), about 900ft. above sea level; *quartz (3in.); barite (3in.); Boulder-clay, 24ft., with small hill blocks; *quartzite (5in.); barite (7in.); Boulder-clay, 20in., stones all small; glacial striæ pointing to valley.

Pitcon Burn enters Garnock 1 mile above Dalry. Large bank of gravel at mouth of burn, mostly of sandstone, shale, limestone, and hill rocks. Stream flows for ½ mile over filled-up bed of old lake, and no boulders seen till Borestone is reached. Porphyrite with very red vermilion felspar above Borestone Bridge; a few porphyrites beside it; limestone (2ft.6in.); Boulder-clay, 24ft., opposite Hagsthorn; bluish kingle (18in.); Boulder-clay, 20ft., on 15ft. of rock; *quartzite with quartz veins (8in.); red porphyrite opposite Langside (11in.); well-rounded kingle (3ft.6in. × 3ft. × 2ft.6in.); *quartz (2in.); porphyrite (5ft. diam.), at old ironstone kiln in Swinlees glen; two others about same size; porphyrite (4ft.6in. × 3ft. × 3ft.), a little above junction with Gowkhouse Burn; porphyrite (6ft. × 4ft. × 4ft.); two others a little smaller; kingle (12in.). Lower limestone crops out a short distance above junction with Gowkhouse Burn, and many large hill blocks opposite Howrat; barite (5in.); Boulder-clay (30ft.), opposite Howrat; *grit (5in.); green and red ash-beds *in situ*; banded felstone, mostly hid; large block of limestone, like an outcrop, lying across stream a little above Howrat; Boulder-clay, 30ft.; sulphate of lime (3in.); some large boulders in the clay on both sides of burn. Large number of porphyrite boulders 60 yards below Largs road, one measuring 13ft. diam. is probably the largest in Garnock Valley; many large limestone boulders below Largs road; grey ash *in situ*, with thin veins of satin spar; grey porphyrite *in situ* 300 yards above Largs road; limestone (2ft. diam.); grey perlite (4in. and 3in.), unique; *quartzite with vein-quartz (5in.); radiated spherulite, only one of its kind seen (2in.); *quartz (1½in. and 3in.), above old road.

Gowkhouse Burn joins Pitcon Burn at head of Swinlees glen. A little above junction Dalry clayband ironstone (13in. thick) crops out. No foreign and not many local boulders observed in this stream. Lower limestone crops out near Connelston at Largs road; some distance above, thin veins of steatite in trap tuff; limestone

(4ft. × 8in.) 450 yds. below old hill road: and limestone (2ft.), last limestone boulder seen: Boulder-clay, 24ft., 400 yds. below old road: grey tuff with 12ft. of overlying Boulder-clay, above road: quartz pebble 300 yds. above old road.

Powgree Burn joins Garnock shortly below Kilbirnie station, having its source 1½ miles N.E. of Beith. The following boulders noted:—Blotched porphyrite (4ft.6in. × 2ft.6in.); dolerite (4ft.6in.), above Kilbirnie station; near old mill in glen waterfall of about 30ft.; in glen limestone composed entirely of small crinoid remains, and of which so many boulders are already noted. It is well exposed in Gurdy cutting of the Kilbirnie Railway opposite. Sandstone (5ft. × 3ft.): syncline in glen above Dalry road; anamasite (5ft.6in. × 2ft.); clayband ironstone, 7½in. thick, *in situ*: large dolerite dyke opposite Roughwood; a good few boulders between Kilbirnie and Beith Railway, mostly dolerites: porphyrites and a few limestones: dolerite column as boulder, with angles very little worn (5ft.6in. × 3ft.); limestone (4ft.3in. × 4ft.): *fine-grained greywacke (10in.): greenstone (4ft.6in. × 3ft.); crinoid limestone, sub-angular (6ft. × 2ft.6in.); a few whinstones from Beith Railway to Gateside; *fine-grained greywacke (16in.); Lower Carboniferous limestone *in situ*, opposite Spears' Institute: *quartz (4in.); two anamasites (3ft. diam.); white sandstone (20in.); *fine-grained greywacke (20in.): greywacke with $\frac{1}{16}$in. glassy quartz (4ft. × 20in. × 12in.), opposite Gateside; a few traps between Gateside and source (under 3ft.): *grey grit with ¼in. milky quartz (3ft. diam.), opposite Langside, 370ft. above sea-level.

Puduff Burn joins Garnock about middle of Kilbirnie. From mouth to Largs road not many boulders. Near Kilbirnie bluish porphyrites (3ft. × 3ft. × 2ft.9in.); dark grey porphyrite (5ft. diam.): *coarse red sandstone with some white quartz pebbles (22in. × 20in. × 13in.); *fine-grained greywacke (22in. × 12in.), 100 yds. above Kilbirnie; *quartz grit (2ft. × 16in.), 40 yds. below Largs road. From Largs road to the large fault which brings up the hill porphyrites from beneath the limestones there are a good many boulders, all hill blocks with the exceptions noted. Some distance above Largs road a cliff 40ft. high, with many open fissures in limestone near the top; and above this the stream, in dry weather, runs in these fissures underground. *Quartz (2in.): small waterfall (10ft.); some distance above, long section of carboniferous shale with numerous examples of *Productus giganteus*

in natural position; *reddish hornblendic felsite, well-rounded (7in.), scarce; *another (15in.); Boulder-clay, 20ft.; fault brings porphyrites up hill; waterfall of a series of steps (40ft.); further up green porphyrite dyke with pink felspar, weathering yellow; porphyrite (12ft. × 6ft.); green dolerite (2ft.9in. × 20in.); barite (5in.), 30 yds. below 20ft. waterfall; above this a few hill blocks.

Pundevan Burn flows nearly parallel to Garnock and joins it at north end of Kilbirnie. Near mouth number of dolerites, porphyrites, and felstones; and from here up to Dobbie's Cottage a good many boulders; dolerite (4ft.6in. × 4ft.); *quartz with green patches (4in.); clayband ironstone *in situ* in glen (12in.); *quartzite (7in.); porphyrite (7ft. × 5ft.); lower limestone crops out a little south of Holehouse; *contorted mica schist (4in.); a short way above limestone outcrop are agglomerate and ash-beds with well-rounded felstone boulders imbedded; the three largest measure 1ft.6in., 2ft.3in., and 3ft. diam.; purple ash *in situ*, with small calcite and barite veins; waterfall over 12ft. of purple porphyrite; *grey grit (8in.); felstone porphyry (16in.); barite (4in.); very little Boulder-clay seen along banks and only near the lower part of stream.

Surge Burn enters Garnock 4 miles above Kilbirnie. Not a great many boulders seen, but the following noted:—near mouth bedded porphyrite dipping steeply in direction of stream; *quartz (2in.); barite (4in. × 8in.); massive red porphyrite *in situ*, probably one of the sources of many of the red porphyrite boulders; Boulder-clay, 30ft., on rock, stones mostly small and all local; barite (4in. and 15in.); quartzite from walls of barite veins (?) at Muirshields; barite (10in.); red porphyrite *in situ*; red felstone *in situ*; *three quartz (2in. and 3in.); Boulder-clay, 10ft., on rock; barite (3in. and 6in.); greywacke (8in.); Boulder-clay, nearly all stones, with very little clay; barite (9in.); *quartz (1in.); barite (15in. × 13in. × 6in.), the largest barite seen, and probably from Muirshields; Boulder-clay, 20ft; few blocks from here to source.

Murchan Burn joins Garnock a short distance below the falls. In lower part some good sections of white claystone, and other dykes to be seen, also sections of rhyolites and tuff beds. About 200ft. from top of Misty Law, a felstone hill which is 1663ft. high, a *quartzite (4in.) seen, and not far from the top *three quartz pebbles.

Besides the above boulders in the beds and along the banks of

the streams in the Garnock Valley, a great number of others were noted in dykes, railway cuttings, and along roadsides; but I shall only note a few of them foreign to the district. At Redstone, near Kilwinning, *mica schist fragment (16in.); *contorted schist fragment (17in.); at Fergushill, mica schist (2ft.6in. × 2ft.); in dykes near Torrenyard, *several grey grits up to 18in.; *fragment of fine-grained grey granite; at Snakers sandstone quarry, *chlorite schist (9in.); *greywacke (4in.); old red sandstone (2in.); *quartz pebbles up to 3in. At Lissens, *granite with pink and white felspar, hornblende, and a little quartz (12in. diam.); *contorted schist (18in.); *greywacke (15in.); *quartzite (5in.) quartz (4in.); *greywacke with $\frac{1}{16}$in. glassy quartz (2ft.6in. × 2ft. × 10in.). In dykes at Auchentiber, *twelve greywackes, up to 2ft.2in.; *two pink quartzites (6in.); *several quartz pebbles, one 18in. diam., and the largest piece of vein-quartz seen; *contorted mica schist (6in.); *milk quartzite with mealy grains; *red sandstone conglomerate (9in.); *Ben Cruachan granite (9in.) fragment; *bluish grit (10in. and 14in.); *fine-grained grey granite (13in. diam.) Drumbue farm, near Kilbirnie junction, *pink quartzite (8in.); Gatend farm, *two greywackes (20in.); grey grit (20in.); *quartz (12in.); *fine-grained grey granite (10in.) At South Bar farm, *granite with yellow and green felspar (12in. × 9in. × 3½in.) At corner of farm-steading, *grey granite with dark patches (2ft. 7in. × 19in. × 9in.), 360 feet above sea-level.

When examining the boulders in this district I asked a farmer if he had ever seen any granite lying about his fields. After thinking a little he said, "Na! na! couldna say: there micht be a daunnerin' yin!" Looking at me for a little trying to knock a chip off a hard boulder, he remarked, "Ye'll be in the heidstane line?" At Barmill, in dyke, *grey grit with ½in. quartz (12in.); *Ben Cruachan granite (15in. × 5in.). These last ones are extra thin for granite boulders in this district, which are generally pretty round. At Mantrap, *fine-grained greywacke (4ft.6in. × 3ft.3in.) with flat surface; *fine-grained greywacke (19in.); *a schist with alternate white and dark green bands (16in.), the only one of its kind seen; *greywacke (12in.).

Near Kilbirnie junction on railway banks, *grey granite (7in.); *Ben Cruachan granite (2ft. × 1ft.6in. × 12in.) with dark patches. Cutting at Barmill railway, near Highgate, *greywacke 5ft. from top of Boulder-clay (3ft.4in. diam.); Boulder-clay reddish brown;

*Glenfalloch diorite, (17in. × 13in. × 6in.); at Wester Highgate, *Glenfalloch diorite (15in. × 12in. × 6in.) Both of these boulders are exceedingly well rounded, and so they may. At Middleton, *Old Red Sandstone (9in.); *Ben Cruachan granite (11in. diam.); North Biggart, *grey grit (22in.). At Giffen, *fine-grained greywacke (20in.); at Tandlehill, *some small grey grits. At Raw, *brown conglomerate (9in.); schist with $\frac{1}{8}$in. garnets. At Hesselhead, *mica schist (20in.); *Ben Cruachan granite (10in. diam.). At Davidshill road-end, *greenish greywacke (3ft.9in. × 2ft.10in.), 230 feet above sea. At Cockenzie, *grey grit (2ft. × 15in. × 8in.); *granite fragment (12in.); *chlorite schist (8in.). Near Dalgarvan, *quartz (11in. × 6in.). At Laigh Smithston *a few small grits. At Monkcastle, *reddish hornblendic felsite. Near Caddel, *contorted schist (11in.); *greenish greywacke (9in.). At Birkhead, west of Dalry, cavity in porphyrite boulder lined with agate and amethyst crystals—boulder probably from somewhere about Baidland hill—the only amethysts observed. At Blair, *greywacke (2ft. × 18in. × 15in.); *another (20in. × 20in. × 8in.). At Gooseloan, *Ben Cruachan granite (2ft. diam.), the only granite block seen imbedded in the Boulder-clay. At Auchenskeith, *a "massacred" Ben Cruachan granite; *greywacke (14in.); mica schist (10in.); kingle (18in.); *_green_ kingle (18in.); *Glenfalloch diorite (12in. × 11in. × 4$\frac{1}{2}$in.). At Bowertrapping, *purple jasper veined with white agate (5in.), the only one of its kind seen. At Fairlie Bog, in railway cutting, *green grit (2ft.9in. × 2ft.). At Woodside, in middle of road, *large boulder of grey grit partly seen. At Weirstone, near Kilwinning, *Ben Cruachan granite (9in.). At Outer Airdoch, *granite with pink felspar (8in.).

From the above enumeration of the Garnock Valley boulders it will be seen that whilst the local ones are numerous, except in the extreme west, they all indicate a dispersion from a north-east source, agreeing, in this respect, with the observed striæ on the rock surfaces. Foreign boulders are much less frequent, and from their mineral characters point to the districts lying between Loch Lomond and Loch Fyne, Glenfalloch, and even so far north as Ben Cruachan, as their native homes, to which, like M'Crimmon, the Highland piper, they "shall never return."

To have come direct from those districts the ice which brought them must have travelled over the high rampart of hills, which, as we have already seen, shuts in the Garnock Valley on its N.W.

side. That some of the ice actually surmounted this rocky rampart I think we have clear evidence of in the Highland blocks observed, *few* as they are, in the higher reaches of the Garnock, Surge, and Routenburn streams. But this could only have happened at the period of the most intense glaciation, when the ice was perhaps not less than 2000ft. thick in the valley of the lower Clyde, and when it may have been much more. We have seen that west of the Garnock erratics from a Highland source are extremely few, whilst on the east side they are comparatively numerous. For instance, west of the Garnock not a single granite block was noted, and in the bed of the Garnock itself only six blocks were counted, whilst east of the river thirty-one granite boulders were catalogued. This fact, together with the striæ observed on the underlying rock surfaces, clearly shows that the stream of Highland erratics entered the Garnock Valley from a N.E. direction, or from one at right angles to that from whence they came.

This latter statement may at first sight seem not a little startling. If we glance at sheet 30 of the 1-in. Geological Survey map we shall see that in the neighbourhood of Kilmalcolm, north of the higher reaches of the Garnock, the glacial arrows, showing the direction of the striæ, all point up the Clyde valley, and look as if they were flying for Paisley. As was first observed by Mr. D. Bell and Professor J. Geikie, the Highland ice did not all find a passage by the Firth of Clyde, and was forced to make its way *up* the Clyde valley, where it was met by the Clydesdale ice near Glasgow, and turned by Paisley and Barrhead in a S.W. direction into the valley of the Garnock; and the position of the Highland boulders in this valley singularly corroborates the observed evidence of the striæ. That the great bulk of the Boulder-clay here is of true ground moraine origin has been already, I think, clearly shown. The only evidence we have of iceberg Boulder-clay being in the lower part of the valley, and at no higher level than 60ft. above the level of the sea, although in the Ardrossan district, not far off, it is found somewhat higher. It might be argued that when the sea stood at a much higher level, 510 feet, when the Airdrie glacial shell-bed was deposited, much of the Boulder-clay might have been deposited from icebergs, and subsequently have been washed away as the sea retreated. Had this been the case, we ought to expect deposits of sand and gravel containing boulders

lying on the top of the true old Boulder-clay. But except in the low-lying districts near Kilwinning, which have been subjected to marine denudation, deposits of this sort were nowhere observed, neither any accumulations of boulders which could not be accounted for by the removal by river denudation of the old ground moraine in which they had at one time been imbedded. The condition of the boulders themselves, too, shows they have not been exposed for a length of time to the action of the atmosphere. The granite blocks, from what we observe on hills built up of that rock, we might expect to have found in a decomposed state had they been long exposed to the action of the weather, are singularly solid, and it is with difficulty, with few exceptions, that a fragment can be detached from them with an ordinary geological hammer.

Under the great ice-sheet the ground moraine, together with the lower part of the ice, from the friction caused by the stones and boulders grating against one another, and on the rock-surfaces over which they were being driven, must have been alternately freezing and thawing, and this may account for the curious veins of sand we sometimes see in the Boulder-clay. It is interesting to note how the ice quarried the material with which to form the ground moraine. Portions of soft shales were crushed up and the clay and stones forced underneath them, then drawn out into long black strings, as was seen in the cutting of the Lanarkshire and Ayrshire Railway at Lissens. (Plate VII., fig. V.) Soft sandstones were first crushed into brecciated material, then trailed along, the fragments becoming rounder and rounder, smaller and smaller, till a band was formed beneath the Boulder-clay almost like a stratified bed, and requiring some care to distinguish it from one. (Plate VI., fig. III.) This is often seen when the Boulder-clay is being removed from the top of sandstone at quarries N.E. of Kilwinning. Where the sandstone is of a firmer nature, and crops out in the direction in which the ice was moving, the blocks were detached purely by friction. We first see a block *started* from its parent bed, with a portion of fine clay about the thickness of a knife blade occupying the joint. The block before it will perhaps have moved half-an-inch, the one before that still a little further, till we have a whole fleet of them, all at varying distances apart, and whose onward progress was only stopped by the breaking down of the machine that set them in motion. (Plate VI., fig. I.) Once a block had been friction-quarried and fairly started on its

way it never seems to have travelled as quickly as the clay and stones which surrounded it, the stones in their turn not travelling so quickly as the clay.

From descriptions we often read, one would think that the stones and boulders were all striated by being rubbed against the rock-surfaces over which they travelled; but though they must again and again have been brought into contact with the rock-surfaces by a sort of vertical gyratory motion of the whole boulders and clay, especially those brought from long distances, still the clay would act by friction on the stones, and both on the boulders, so that in such a way they would become striated to a certain extent. It appears to have been a sort of understood arrangement that "if you claw me I'll claw you." The fact of the whole deposit having undergone this kind of motion is proved by the great uniformity in the whole mass where it passes over rocks of firm consistency. Had this not been the case we should have found it banded of all shades of colour, the lowest band taking the shade of the latest rock over which it passed. But colour-banding is found to be very local and confined to patches of the Till where the underlying rocks are soft and easily quarried. The bottom part of the ice would move faster than the surface clay, and it again quicker than the rest of the clay—that at bottom for the time being moving slowest of all from the greater friction it would have to undergo.

Boulders have been moved along with a sliding-rolling motion, and long boulders have constantly gone "head over heels." They have never moved with a side or "row chow" motion, which is proved by the fact that they are found at all angles in the clay, and even standing in a vertical position (Plate VI., fig. II.), and they are striated longways generally, although there are a few exceptions to the rule. This could not have been the case if they had moved sideways, or even have been hauled along in a uniform "end on" direction. Another strong argument in favour of the deposit having been thoroughly mixed in the way indicated, and under immense pressure, is the fact of its extreme toughness—a man with a pick being scarcely able to remove a larger bit at a time than the size of one's hand.

Wherever striæ were observed in steep-sided glens, such as that of the Garnock where the cross section is V-shaped, it was always seen to be in the direction of the glen, whilst the glaciated surfaces

of the rocks on the moors adjoining perhaps pointed in a different direction. This might be ascribed to a subsequent local glacier, but I think not. I am inclined to believe that the ice and ground-moraine always moved in the line of such glens, and that the ice-sheet went sheer over the top of them independently of their direction. This may not necessarily have prevented such glens from receiving foreign blocks which, passing either along or across its direction, would have a tendency to *burn* into the ice that filled the glen and be deposited in it. Where glens are wide and open the case would be altogether different, the *whole* of the ice-sheet moving slantwise or even directly across them, but no doubt influenced more or less by the slope of the ground, as we see it has been everywhere.

There are in the Garnock Valley some bold glacial escarpments. That near Barmill and Giffen castle, formed by a wide trap dyke already noticed, which extends for a length of $2\frac{1}{2}$ miles, has received the full force of the ice grinding over it from N.E., and makes a considerable figure in the landscape, having considerably protected the strata to the south. The Blair and Giffen dolerite escarpment runs for a distance of $3\frac{1}{2}$ miles, and looks like a line of old sea-cliffs. It received the ice in a more slanting direction than the one already mentioned. Monkcastle and Tower are also conspicuous glacial escarpments, the former rising 260 feet above the bottom of the valley.

Amongst the Dalry and Kilbirnie hills the *roches moutonnées* are to be reckoned by the score, and all give evidence of the direction and intensity of the great ice movement. Before the advent of the glacial epoch the hills in this district no doubt presented a very different appearance from what they now do, being in all likelihood much higher and more pointed, and it is not unlikely that the cones of the old Miocene volcanoes, of which we now find only the "necks," then "towered to the sky." But all this is changed, and the hills are "sow-backed," with strong "crag and tail," showing that the great ice-sheet passed over their very summits, high as some of them now are (Plate VIII., fig. XI.). In the middle part of the valley, and especially E. of the Garnock, the surface, where not broken by projecting outcrops of the harder rocks, presents long sweeping guttery and curved surfaces, like large ridges and furrows, and in the latter run the streams which drain the district. The ridges are so conspicuous as to have

suggested names in the olden times to several districts, such as Lugtonridge, Swinridge, etc. That the movement of the ice had to do with the formation of both ridge and furrow I think there can be no reasonable doubt. They have been formed without respect to the dip of the strata from which they are carved, and in many instances the Boulder-clay is thicker *on the ridges* than in the furrows between them.

In the lower part of the Garnock Valley, from a short distance above sea-level up to about 200 feet, the country is singularly hummocky, and the hummocks or drums are so conspicuous at this level that at this part it might not inappropriately be called the "Drum Country." These drums are entirely of Boulder-clay, up to 40 or 50 feet in thickness, and seem to have been carved out of the longitudinal ridges already mentioned (Plate IX., fig. XIII.) when the land was subsiding below the sea-level, and modified no doubt when it was again rising.

[Since this paper was in type, the Seventh Annual Report of the U.S. Geological Survey has come to hand. Prof. Chamberlain, the author of the Memoir on Ice Scorings, gives it as his opinion that the Boulder-clay drums or drumlins were formed by the *second* ice-sheet, which carved them in a manner similar to that in which it acted when passing over syenite districts. This appears to me to be a very feasible explanation of the formation of drums, but in the case of our Ayrshire ones, there can be no doubt that the sea has been amongst, at least, the lower lying ones. Jan. 1891.]

As already mentioned, when the glacier and its Boulder-clay passed over soft rocks, such as shale, soft sandstone, and ash-beds, tearing up and crushing of the rock took place. Should harder rock be passed, the tear and wear on the soft and the hard rocks would be very unequal, the ultimate result being the formation of a rock-bound hollow as first suggested by Sir A. Ramsay, and when the ice melted away such hollows would become filled with water, forming a loch like Blae Loch, the basin of which has been scooped out of the ash-beds below the lower limestones. Indeed that part of the Garnock Valley between Kilbirnie and Kilkush is such a rock-bound hollow scooped out of the Lower Carboniferous shales and sandstones, the bottom of which at some parts is just about sea-level.

In the progress of such a mass of glacial ice as that under

consideration one might expect to find that it had left a very thick accumulation of Boulder-clay—*a mixture of all the rocks over which it had passed.* But we have seen that this is not the case, and that it partakes more of the nature of the rock over which it had *immediately* passed. A ground-moraine glacier must therefore have some way of getting quit of a lot of its material as it moves along. It is well known that a glacier discharges, at its lower end, a large quantity of *muddy* water, which comes from the ice melted by the heat generated by the continual friction. This appears to me to have been the manner in which the great ground-moraines got quit of a large quantity of their accumulated material in the shape of fine *mud*, and which was possibly deposited on the ocean bed. At the lower end of the glacier, where the quantity of water was greatest, *all the mud* would be naturally washed away, and hence it is that at the end of modern glaciers there is not any *Till*, but only moraine matter, all the clay having been washed from amongst the stones.

The farther a stone travelled in the ground-moraine it would likely, according to its hardness, suffer the more. Hence the granites from Ben Cruachan and hornblendic felsites from Glenfalloch found in the Garnock Valley are all small blocks, while the softer red sandstones, which have not travelled half the distances, are reduced to mere pebbles. On the other hand, many of the local blocks, which have only been moved for a few yards, have their angles remarkably sharp.

We have seen at Lissens that blocks of sandstone were torn from the *end* of beds (Plate VI., fig. I.) merely by the friction on them of the ground-moraine aided by the pressure of the super-incumbent ice. But the glacier had greater power when it came to push against a hill-face. As the ice began to gather and thicken, the loose blocks from the higher crumbling faces would be the first to get frozen into its mass. When a hill got entirely enveloped in the ice, mechanical force would come into play, shoving at first all the loose blocks from the shoulders and summit. As the ice increased in force and power, blocks more firmly fixed would be torn off and borne away. But we see from the rounded, striated, and smoothed tops of the present hills that there was a limit to this wholesale *quarrying*, and that the ice, aided by the rocks frozen into it, acted as a rasp or file, rubbing away such particles as it could detach from the compact rocky surface, and

in this way we have those bald-headed hills with long grassy tails so common in the Kilbirnie and Dalry districts (Plate VIII., fig. XI.).

Where the action of the ice was not continued long enough to plane the brow of the hill down to a resting slope, or where perhaps there were more easily abraded rocks further down on the stoss side, we have left there steep hill-faces directed to the north (Plate VII., fig. VII.), where subsequent weathering has detached many angular shivers, which now form a long brecciated scree on the hill-slope so very different from a ground-moraine, although, like it, partly the product of ice.

As to the average thickness of the Boulder-clay in the Garnock Valley, it is of course impossible to form a correct estimate. We have seen that in some favoured spots it attains a thickness of 70 feet, and I think this may be taken as about the maximum. But taking the whole area, hill and valley, the average thickness will not probably exceed 10 feet. There is of course much more of it, area for area, in the lower part of the valley than amongst the hills.

There is an almost entire absence of moraines in the Garnock Valley, and I can only point to a very small lateral one 90, yards long by 30 yards broad, on the lands of Swinlees, and another near the head of the Lugton Water in the valley a short distance beyond Lochlibo. From the abundant evidence we have of such a mass of ice having for a long period passed over the district, it may at first seem a little startling that moraines are not both large and numerous, but when we reflect that the movement of the Garnock Valley ice owed its mechanical energy, not to any power within the valley itself, but to the outside pressure from the combined ice coming *up* the Clyde from the Highlands, and that coming *down* the Clyde Valley from the higher reaches of Lanarkshire, we shall see at once that so soon as the ice-sheet had sufficiently melted to allow of it *all going by the Firth of Clyde*, the ice in the Garnock Valley would simply be brought to a standstill, and, with a few local exceptions, just melt where it stood. I think that in this way we may explain the absence of moraines in the Garnock Valley.

During a recent extension of railway lyes at Kilwinning station a section of Boulder-clay was laid open which was seen to be contorted and curved in a most remarkable manner (Plate VII., fig. VIII.). After studying this curious section for some time, I came to the

conclusion that the contortion could only have been brought about by an iceberg grounding, the ice having been pushed for some distance in amongst the beds of Boulder-clay, sand, and gravel, curving and twisting them in the most fantastic manner. The age of the sand and gravel beds could not be ascertained owing to the entire absence of fossils in them, but it is not improbable they are Post-tertiary, as we have no evidence of icebergs having frequented the seas in this quarter during the Raised Beach period.

We often hear geologists speaking of lake hollows and depressions as *pre-glacial* because they *contain* Boulder-clay, and it is answered of course that the hollows are older than the Boulder-clay they contain. I cannot admit of this style of argument, for the process of hollowing out such "depressions" and "basins" can only have terminated through the machine and tools by which they were formed—viz., ice and Till having ceased to act—so that they cannot properly be termed pre-glacial, but must be called synchrono-glacial, as having been formed at the same time as the Boulder-clay which they contain. In the gritty sandstone districts of Pencot and in some parts of the upper portion of the Caaf area, Boulder-clay is either absent or very thin.

It has often been remarked that Craigmaddie Moor, north of Glasgow, is singularly free from both Boulder-clay and even boulders; and geologists well know that in districts where hard gritty sandstones belonging to the millstone grit formation occur the surface deposits are conspicuous by their absence, which peculiarity has earned for this series of strata the very appropriate title of "moor rock." This fact of the absence of Boulder-clay in such districts has never been explained so far as I am aware. But I think it can be very easily accounted for. If we take a piece of rock—say a small fragment of limestone—and rub it on a slab of shale, we shall find that by rubbing even for a very long time little or no effect is produced on the limestone. But let us substitute for the shale a slab of gritty sandstone, and matters are very much changed. Even under the comparatively feeble pressure of the hand the limestone gets "smaller and beautifully less" till it ultimately is resolved into dust. Similarly the Boulder-clay, in passing over a shale district, will suffer very little abrasion *from the shale*, but in being forced under the pressure of ice over a coarse gritty sandstone, the boulders, even the very hardest of them, will soon be rubbed away and ground into mud, and for the same reason the

ice itself will suffer much more from friction—that is to say, a greater quantity of it will be converted into water, so that the mud produced from the grinding down of the stones and boulders will have a greater chance of being carried away by the streams which are constantly running under glacier ice. Thus the thickness of Boulder-clay in any district will be very much influenced by the nature of the rock over which it is being driven, and in gritty sandstone districts it may be very thin or entirely absent.

The average depth of Boulder-clay for the whole Garnock Valley area is probably not now more than 10ft., but I think this gives a very poor idea of the work done by the ice in this district during the Great Ice Age. From the rounded contours of the hills, from the probably high Miocene volcanic cones of lava and loose ashes now quite obliterated, and the hollows dug into the softer shales, the total average thickness of rock material abraded from the surface area of the Garnock Valley was probably very many times the amount of the Boulder-clay deposit still left. We have seen how rapidly the Till changes its character in the different districts in which it is found, taking almost at once the character of the rock over which it has immediately passed, or on which it may be resting, proving how large an amount of material glacier action was capable of grinding up and getting rid of as mud. We have also seen in the Surge Burn district, where the rocks are very hard, the Till has very little clay mixed with the boulders and stones.

Wherever an opening is made or natural section occurs in the Boulder-clay it is seen that 4ft. to 6ft. of the upper part from the surface seems at first sight to be a different and subsequent formation to the under part. For a long time I considered it to be so, but on closer study it proved to be simply "part and parcel" of the *moraine de fond*. Its browner or rustier colour and more open texture than that of the lower portion appears to have been caused by the greater weathering it has been subjected to, water and air having penetrated into it and acted on its constituents so as to render it opener—in fact, a first step towards its reduction into soil. On the soils resulting from Boulder-clay the best oats in the world, for which Scotland has been, as may it long be famous, are grown.

We have seen that vein-quartz pebbles are more or less scattered over the Garnock Valley, as they are over large parts of the surface of Scotland. No doubt some of these, if carefully assayed, might

be found to contain payable quantities of gold, and in this way, by tracing up the reefs from which they were originally derived, valuable discoveries of gold-bearing quartz might be made. An old quarryman informed me that where Boulder-clay is "creeshy" the sandstone rock below it is sure to be good; the reason being, I suppose, that the overlying "creeshy" clay is impervious to water, which, if allowed to pass down through the sandstone, would carry away its binding carbonates.

We have seen that at Lissens blocks of sandstone have been drawn from their positions and carried off in the Boulder-clay simply by the friction of the Till and ice grinding over the sandstone bed. Amongst the hills a few instances occur where blocks of porphyrite have been drawn down from the *tail end* of large *roches moutonnées* (Plate IX., fig. XII.), and are left lying at varying distances in the direction in which they were being carried off, the parent rock being angular and broken, and presenting no rounding or signs of glaciation except on the top.

Within 50ft. or so of the top of Misty Law there is an accumulation of rock shivers arranged as if they occupied the site of an old sea-beach. In fact, at first sight one would think the tide had but recently left them. The shivers are all of small size and extend for some little distance along the S.E. front of the hill. They are rather difficult to account for, and are lying far too flat to have formed part of a scree of rock débris. We know that in the Arctic regions the ice-foot breaking up during summer carries along and deposits angular rock-fragments in the form of regular beaches. A sheep farmer I met on the hills informed me that there were similar accumulations of shivers on several parts of the moors, and at much lower altitudes than those on Misty Law. This matter is certainly worth further investigation, as it may be the means of showing that the sea since glacial times stood at a much higher level in Scotland—as it is supposed by some geologists to have done in Wales—than we have elsewhere any proof of.*

Prof. J. Geikie thinks that, when the ice had melted from the lower reaches of Lanarkshire, the Lochlomond glacier, issuing into the Clyde at Dumbarton Rock, blocked up the passage, and the river accumulating in an inland loch near Glasgow, rose high

* Since this was in type it has occurred to me that these deposits of rock may have been carried down from the hills by snow.

Fig. I.—Section, at Lessens, shewing how Sandstone blocks were friction-quarried. Arrow indicates direction of Ice movement.

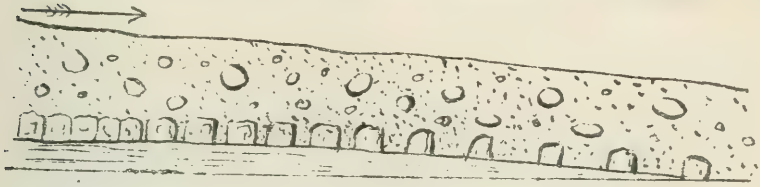


Fig. II.—Section near Kilbirnie, shewing Sandstone block, 5 ft. long by 20 inches, right on end in Boulder-clay.

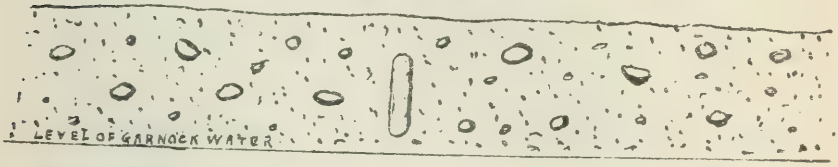


Fig. III.—Section of Boulder-Clay, Snaker's Quarry, 12 ft. high. Sandstone with clay joints 2 to 3 ft. down, at S. Above it angular pieces of Sandstone not long taken up by Till. Till near rock is very sandy, and shows horizontal shear planes looking like lines of stratification.

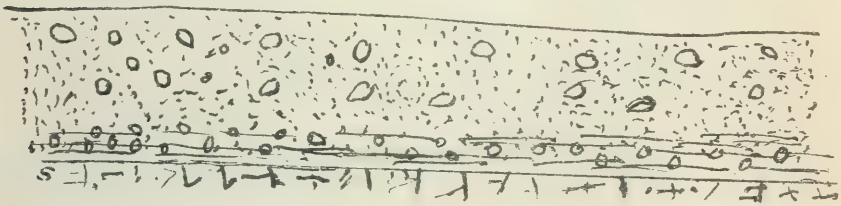
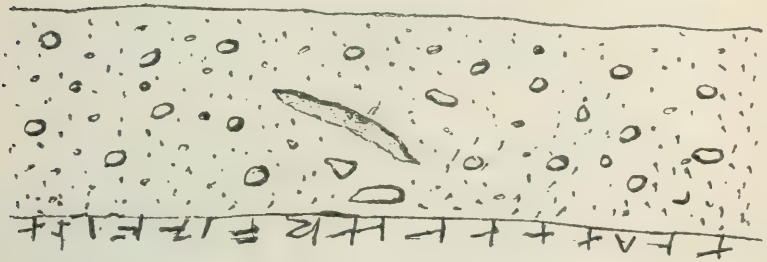


Fig. IV.—Section of Boulder-clay, Snaker's Quarry, with patch of pure sand 6 ins. at thickest part and 4 ft. long. Muddy sand in the pure sand at A.



JOHN SMITH DELT

SECTIONS IN THE GARNOCK VALLEY.

CARTER & PRATT LITHOS

Fig. V.—Section, at Lissens, shewing crushed-up mass of black shale with Boulder-clay under it resting on crushed black Carboniferous shale.

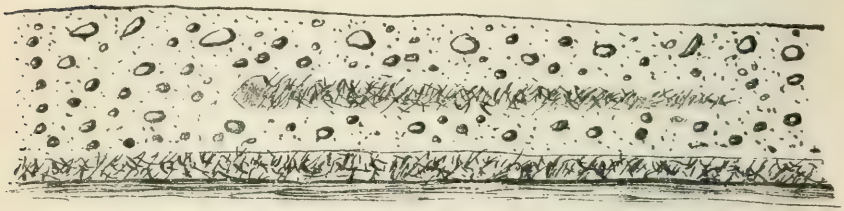


Fig. VI.—Section of Smithstone Dolerite Quarry shewing Boulder-clay occupying a hollow where the rock is soft. No Boulder-clay on top of hard rock.

Fig. VII.—View of Glenfon (790 ft.) and Gill Hills, shewing "Crag and Tail."

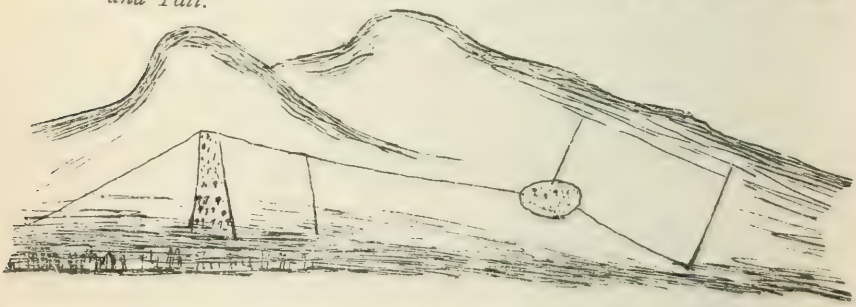


Fig. VIII.—Part of a section (6 ft. high) near Kilwinning station shewing, at B, Boulder-clay (Ground Moraine) crushed up amongst contorted sand and gravel beds, A.

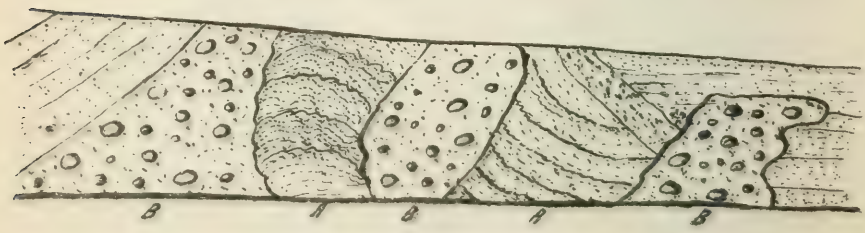


Fig. IX.—Section near Smithstone House, 22 ft. high, shewing Icebergs, Boulder-clay, stratified sand, and Ground Moraine.

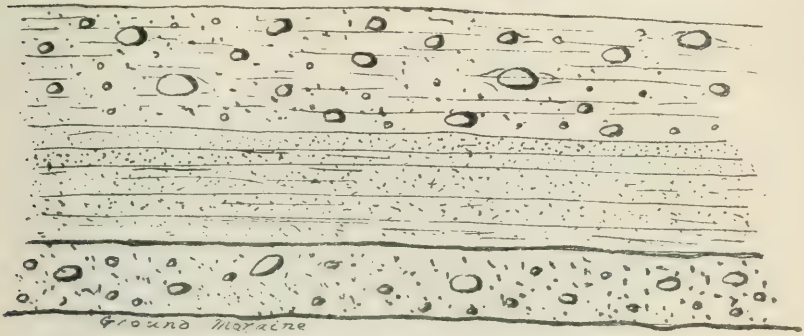


Fig. X.—View of the Volcanic Necks, in Carboniferous strata at Castle Hill, near Kilwinning, shewing "Crag and Tail."

Fig. XI.—View of top of Misty Law, 1663 ft. high, shewing "Crag and Tail."

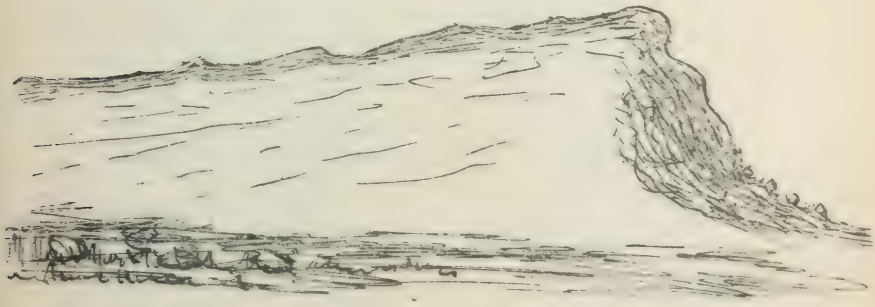
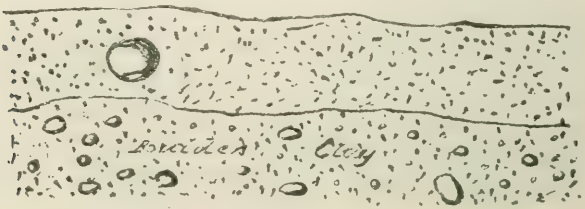


Fig. XII.—View of Lamb Hill, Ladyland Muir, shewing "Crag and Tail," and how rock at Tail end has been friction-quarried and the blocks of stone mostly carried away. Tail ends called "The Rotten-craigs."

Fig. XIII.—View of part of Drum Country near Flemland, shewing how longitudinal ridges of Boulder-clay become broken up into Drums. Arrow indicates direction of Ice movement.

Fig. XIV.—Section at side of Sourlie Ry. shewing boulder 3 ft. diam. embedded in gravel, 90 feet above sea level.



enough to be able to flow *viâ* Lochwinnoch and Kilwinning to the sea, so that what we now call the Garnock Valley was then the lower portion of Clydesdale. I see nothing to hinder this to have been the case, and it was probably during this time that the deep hollow from Dalry extending away in the direction of Paisley was partly filled with sandy clay and mud—Lochwinnoch and Kilbirnie lochs being the only parts not yet entirely filled up, the former of which will very soon be, but the latter will remain a loch for a long time yet. It was probably also the Clyde that cut the passage through the thick Boulder-clay at Monkcastle, where so many boulders are now seen in the bed of the Garnock. Had this not been accomplished when the Lochlomond glacier blocked up the Clyde at Dumbarton, the Caaf, having for tributaries the Rye, Garnock, Maiche, Calder, Gryfe, and White Cart, would have flowed into the Clyde at Renfrew. We have already seen that wherever the rocks are of a soft nature they have suffered to a much greater extent than where they are harder. We see this in a very marked manner at Smithston dolerite quarry, where a hollow has been worn in a soft part of the rock and contains Boulder-clay, whilst there is none where the rock is hard (Plate VII., fig. VI.).

In conclusion I have to express my thanks to Messrs. Peach and Bennie of H.M. Geological Survey for information about some of the boulders noted in this paper.

No. XI.—Notes on Gairloch, Ross-shire. By James White, *Hon. Librarian.*

[Read 11th October, 1888.]

Gairloch is the name of a parish and of an arm of the sea in the west of Ross-shire. The parish is a large one, being about 30 miles long by 20 broad; the arm of the sea is 4 miles long by 2 broad at its entrance, and is distant from Oban about 140 miles, or eleven hours' sail. The sail from Oban to Gairloch is a popular one with the tourist, the sight-seer, the health-seeker, the archæologist, and the student of physical geology, as it presents features which call up associations of surpassing interest. It is, however, with its geological aspects that we are at present concerned.

Few geologists are unacquainted with M'Culloch's volumes descriptive of the Western Islands of Scotland, and few of them fail to appreciate the great amount of labour and care necessary for their production. Whatever imperfections they may have when viewed in the light of the present day, they are a wonderful monument of industry and painstaking for a pioneer geologist.

Then these are the waters traversed by the "Betsy;" and if the Free Kirk never did any other service to the cause of geology, it deserves to be thanked for this, that it afforded Hugh Miller an opportunity of exploring regions and localities which otherwise would have been to him impracticable, and so enabled him to write some very fascinating books, which showed an enormous advance upon the then existing state of knowledge upon their various subjects.

Coming down to more recent years, Prof. J. W. Judd has read the geology and specially the petrology of these western regions with a fulness and a clearness hitherto unattained. His papers on the Secondary and on the Volcanic rocks of Scotland bulk largely in several volumes of the *Quarterly Journal of the Geological Society*, and may be said to mark a new departure in the study of the science. That on the volcanic rocks (*Q. J.*, vol. xxx.) is of special interest. The author has traced, especially in Mull, the passage of one kind of volcanic rock into another all through the various stages from tachylite to gabbro. He has shown that they have a connection, a common origin, a common descent, which it is neither fanciful nor unscientific to describe as a vital one, and so has added another and what seems to be almost the crowning

triumph to the doctrine of uniformity so closely associated with the name of Lyell. For this is really the principle which underlies and gives stability to all scientific progress. Interpret the past by the present, take your cue from nature itself, reason from what is going on around you to what has always gone on, from what is known to what is more obscure.

Then we have recently had from the pen of Dr. Archibald Geikie an apparently exhaustive sketch of the sequence of events comprised in the history of these Tertiary volcanic rocks. One quite wonders at its comprehensiveness and its mastery of detail, and how, from materials which are so very fragmentary, so complete a narrative could be constructed.

With such recollections in his mind as he is piloted through amongst these old volcanic stumps—Mull, Ardnamurchan, Rum, Skye—your geological pilgrim has something akin to those feelings of reverence which a Mahommedan may be supposed to have as he enters Mecca and sees before him in very truth those objects whose story has been told him so often and so vividly. Or like those of a Christian as he enters some venerable cathedral and gazes on its lofty proportions, its richly-stained windows and its magnificent paraphernalia of altar service seen through a "dim religious light," and thinks of what all this is intended to conserve.

Gairloch is cut out of the rocks described by Murchison as "fundamental gneiss." This term, however, must be understood as generally applicable to the whole formation of which those rocks form a part. At Gairloch they are not gneiss, but schists, with occasional beds of hardened sandstone, and are far less metamorphosed than those rocks with which we are so familiar on the northern shores of the Clyde.

The Torridon sandstones, which occur in low-lying masses on the north side of the loch, and appear in great force on the south, form a magnificent background to the bare dome-shaped masses of the gneiss, and overlie it with the most marked unconformability. Those quartzites, which, unconformably, cap the sandstones, form in places the basement beds of a comformable series, some of which are fossiliferous—the uppermost, the limestones, having yielded fossils of a distinctly Silurian character. These fossils have determined the age and relations of the rocks in this neighbourhood. The uppermost conformable series is described as "Silurian," the underlying unconformable Torridon sandstones as "Cambrian,"

and the still more unconformable gneiss as "fundamental," the local names being "Hebridean" or "Lewisean," or "Laurentian," to name them in accordance with the usual geological scale, the physical breaks being recognised as forming these several divisions. By most writers these lowest "fundamental" rocks are described as "Archæan," and are excluded from the palæozoic series.

This, I presume, is in strict accordance with the present state of knowledge, as nothing to undoubtedly indicate the presence of life has hitherto been seen in them. It is obvious, however, that this is quite a provisional arrangement, there being many horizons which yield no fossils, but which overlie, and are therefore of later date than, strata which are fossiliferous, so that the absence of organic remains is not of itself sufficient evidence of their age, or to show that they have never contained any fossils; as these would in all probability be few in number, simple in character, and may very readily have been obliterated by the great changes through which those rocks have passed. At the same time it seems highly probable that sedimentation may have been carried on at a date long anterior to the appearance of living things, and under conditions in which life, as known to us, would have been impossible.

The organic world is supported from the inorganic, the plant and the animal from the mineral, but neither plants nor animals can live on stone, hard rock, or solid mineral by itself, their food being taken in a gaseous or fluid condition, and requiring to be prepared for them; so that the rocks of the first formed, the first condensed crust, must have been highly pulverised and finely divided before life could find a footing, and this could only be done by the agency of water.

Speaking generally, plants live on minerals, animals live on plants. When pushed to its lowest limit, however, the distinction between these two great kingdoms disappears, and the most arbitrary characters have to be selected to define the one from the other. The outstanding rule seems to be that the simple precedes the complex, the less precedes the more highly differentiated; and accordingly we find that what evidence there is for the existence of life in those Archæan rocks is referable to the plant rather than to the animal. An animal is more highly organized than a plant, has a greater number and a greater variety of parts, is better furnished with the means of offence and defence, and, according to this theory, would appear later in time.

Although no clearly recognisable well-defined fossils have been seen in these Archæan rocks it by no means follows that they were destitute of life. The *Lingula*, though it has persisted down to the present day, doubtless had an ancestor which was not a *Lingula*, and the *Oldhamia radiata* sprang from something which preceded it, and so with the other and more highly differentiated forms which Cambrian rocks bring to view.

The boundary of the palæozoic system is wholly unknown. Advantage is taken in this case of a well-marked physical break as a dividing line, but it is entirely arbitrary, and may at any time be thrown indefinitely backwards.

But this whole subject, which is replete with interest, is very fully discussed by Prof. Dana in his "Text-Book."

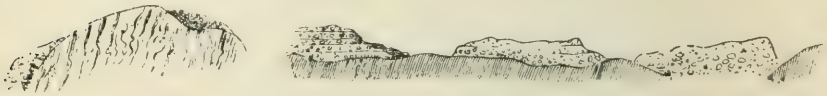
At Gairloch these rocks vary very much in their character—some are quite hard and splintery, others are softer and not far removed from an indurated shale. Beds of sandstone also occur here and there; evidently they are mechanically-formed shore deposits, and have at one time been a series of sandstones and shales such as we are familiar with among rocks of later age round Glasgow. The plane of schistosity coincides with the plane of bedding, the dip is vertical, and no means are here available for estimating their thickness. It seems, however, that further north they are thrown into a series of synclinal and anticlinal folds, from which they have been estimated to be at least 20,000 feet thick; but nowhere is the base visible. There is another feature of these rocks of unusual interest—the extremely rounded bossy forms into which they weather. Many other rocks, especially schists, take this form, but these have received it and retain it in an unusual degree. As you sail into Gairloch and gaze on their dome-like bleached and barren masses in the full glow of the afternoon sun you are at once struck with this peculiarity; nothing like it has occurred all the way, though you think you have exhausted every form of rock contour of which nature is capable. They have an almost ghastly look, innumerable knolls of a bare, dull, verdureless, ashen grey. These rocks are overlain by the sandstones, and, singular to say, in places where the junction of the two can be traced, the rounded bossy form of the gneiss is seen to persist under the sandstone. Clearly it had acquired it before the sandstone was laid down.

This rounded bossy form is by all geologists attributed to the

action of land ice. Wherever it is found, even in tropical countries which are now even farther out of the reach of such action than our own land, it is accepted as proof that "John Frost" has been there, for there is no other known agency which can produce such features. Elevation from beneath is out of the question, as these Gairloch schists stand on end; and for the same reason a puckering up of the crust by lateral pressure is out of the question. Atmospheric weathering gives us stacks and needles and other splintery forms, but a heavy mass of moving ice coming on a country which has been previously subjected to atmospheric weathering planes off the asperities which are thereby produced, and leaves instead bossy rounded forms, which may be either great or small according to the condition and character of the land at the time of its advance.

The plain inference from all this is that we have in these Gairloch schists an example of glacial action in early Cambrian times.

Dr. Archibald Geikie was the first to notice this, and to call attention to it in a paper (*Nature*, Aug. 26, 1880) which he illustrated by some drawings and a diagram of two sections; the latter I have



a *b*

here reproduced. The first (*a*) occurs a little way up the hill immediately behind the Gairloch hotel, and the second (*b*) on the shore immediately to the south of the Free Church.

The Duke of Argyll in a communication to a subsequent number of *Nature* challenged the accuracy of the drawings.

Not having seen the localities of the drawings I don't discuss them, but having gone over the originals of the sections several times I can testify that they are not at all exaggerated; in fact if I had drawn them myself I would have shown the rocks as much more rounded than they are represented. I think most of you will be of opinion that these contours are not such as splintery schistose rocks standing on end would acquire from ordinary atmospheric weathering.

There are other features in the neighbourhood which point in the same direction, as, for example, the extremely rough angular character of the breccia which lies immediately on the schists.

Many blocks in it are from 3 ft. to 6 ft. long, all derived from the underlying rocks, and as sharp and angular as if they had been split off yesterday. Clearly such a mass of material was never brought together by the agency of water; it is vastly more like moraine matter which has not travelled very far.

Prof. Sir Andrew Ramsay, in his address to the British Association Meeting at Swansea, of which he was president, quotes this section of Dr. Geikie's in illustration of the subject of his address, "On the Recurrence of Certain Phenomena in Geological Time." Amongst other recurrences he finds what is to him satisfactory evidences of that of glacial phenomena, and writes:—"The general subject of palæozoic glaciers has long been familiar to me, and this account of more ancient glaciers of Cambrian age is peculiarly acceptable."

Poolewe is worth a visit were it only to see the débris of what must have been a very massive glacier, which, there is so much evidence to show, at one time swept down to the sea through the valley now designated Glen Docharty, Loch Maree, and Loch Ewe. This débris is of the most imposing character; you have boulders on the hilltops cutting the horizon in the most fantastic manner, and boulders strewn along the hillside, boulders single, boulders in groups, boulders angular, boulders rounded, boulders of sandstone, and boulders of gneiss. It seems reasonable to conclude that all this matter is the product of the latest glaciation of this valley, as these boulders appear to be local. I went up the hillside about 400 feet, and all that I saw were schists or sandstones. If those on the tops of the hills are also local, then they probably belong to the same period of glaciation, and in this case the ice must have quite filled the valley and have been sufficiently high above it to strand stones on the ridges. It would then be better described as a *mer de glace* than as local glaciers.

The stones at the bottom of the valley are all smaller and more rounded. Clearly they have suffered more attrition than those on the hillside, and have formed a moraine which has stretched across and filled the whole valley. A retiring glacier turns into a river, and these stones, as they have been acted upon by water more recently than by ice, are now just a mass of very coarse gravel. From a change of level the River Ewe now cuts through this moraine, and the sea, entering from Loch Ewe, cuts into it, so that we have along the banks of the river and at the head of the

loch a very well-marked terrace, which might be described as a Raised Beach. Nothing could be plainer or more evident, and it is worth going all the way to see. We have here the closing stages of the Ice Age clearly indicated in a rising land, retreating glaciers, and an ameliorating climate.

But all this work is of an entirely local character, limited in time, limited in space, and, although we had read twenty such localities, or all the superficial features of the county put together, we have not read the history of the Ice Age. It cannot be seen in the superficial features of the country; you must dig for it, as it is from the digging that the revelations come. What about those six distinct and separate Boulder-clays which some deep bores pass through (see *Transactions*, vol. iii., p. 133), each separation being indicative of a period when the formation and deposition of the clay was suspended and its place taken by sand or gravel or mud, materials which are in no way connected with a cold climate, and which could not by any possibility be brought together under the same climatic conditions as Boulder-clay; and these not occurring in small lenticular patches, which prove nothing either one way or another, but in wide spreading beds 60 ft. to 100 ft. thick?

We must take the maximum number of these indicated changes as the minimum number which has occurred, and so the question is at once raised, how often has this valley of the Ewe and how often have similar valleys been blocked up with this débris and then wholly or partially cleared out? Are we, after all, sure that all the material we see is the product of the *latest* glaciation? According to theory, 20,000 years would be the interval between each period of intense cold, but this is short. According to theory, 80,000 years have passed away since the last period. All the big stones you see are local schists and sandstones, the rocks which lie in the line of the passage of this glacier; but how many glaciers have passed down this glen, and have the lines of drainage which pass into it always been the same? Physiographers point out to us very clearly changes which have taken place in some of the watersheds of the country, and ice-sheds obey the same laws as watersheds. Is it a far-fetched, ill-informed thought that there may be stones amongst those hundreds which you see strewn along those hillsides, or those millions which cover the bottom of that valley, which, as to their derivation, may be widely separated

from each other both in time and locality? There are many districts which could furnish schists and sandstones; the same kinds of rocks have been forming ever since time began. The late Mr. Pratt, a well-known member of this Society, spent a large portion of his leisure time in sectioning crystalline rocks, and all his acquaintances had commissions to pick up for him specimens of them wherever they might come across them, the result being that he came in time to possess a large number of sections—over 300. As the sources of supply from rocks *in situ* became exhausted he collected specimens from the Boulder-clay and sectioned them, thus gathering another series of sections, a great many of which were of quite a different character from his first collection. These he could not possibly identify with the rocks found *in situ*, although he was in every case careful to note the locality where the parent boulders had been found.

In Dr. Croll's book on "Climate and Time" a chart is given showing the probable centres of dispersion of ice during the period of maximum glaciation, and one of these centres is in the North Highlands, where the land rises to between 3000 ft. and 4000 ft. The subsequent detailed mapping of that district by the officers of the Geological Survey has unexpectedly brought to light the fact that this was a mistake. So, as these centres of dispersion all balance and are all related to each other, if one has to be changed so must the others, leading probably to an entire reconstruction of the chart in question, and to still wider conceptions of the extent and thickness of the icy covering.

Then as to submergence. It is Dr. Croll's, and I think the general belief, that the change in the relative levels of sea and land was brought about rather by an advance of the sea, due to the displacement of the earth's centre of gravity by the great mass of ice at the pole, than to an actual sinking of the land, or at least that this was a powerful factor. Should this be correct, then, if we are to have a greater weight from a greater thickness of ice than was at one time supposed, so we must also have a greater submergence than was at one time supposed.

Such are some of the thoughts which in my own way I have had the temerity to ventilate in view of some discussions which have recently taken place in this Society and elsewhere. It seems to me that, in these matters, as generally in nature, it is impossible to draw hard and fast lines; that there is room enough for all;

that geologists cabin, crib, and confine themselves by taking too limited a view of such operations; and that if these are looked at in their true proportions much difficulty might disappear. Within its real compass we may quite well have boulders, many stranded by retreating ice, and we may also have boulders, many of which as certainly have been dropped from passing icebergs. In some cases the difference is quite easily defined, in others it is by no means evident. May they not sometimes lie side by side?

When we have a past president of the Geological Society telling us that the ice-cap in Scotland was 3000 ft., and in some places 5000 ft. thick; and another past president telling us, just the other day, that there never was an ice-cap in the country at all; when we have geologists who contend that there is no evidence whatever to show that the land was ever sufficiently submerged to allow icebergs to float over it and drop erratics on its surface; and other geologists who contend that all the glaciation which it has undergone has been due to floating and not to land ice at all, it is surely apparent that there is a vast deal of speculation going on, and that more careful and cautious and accurate observation than has hitherto been bestowed on these questions is called for.

So much for another glimpse of "our stern Scottish Highlands," a land famous in song and story, and a land of perennial and ever-increasing interest to all dabblers in physical geology.

[Permission to reproduce the sections on page 196 has been kindly given by Messrs. Macmillan & Co., London, the publishers of *Nature*.]

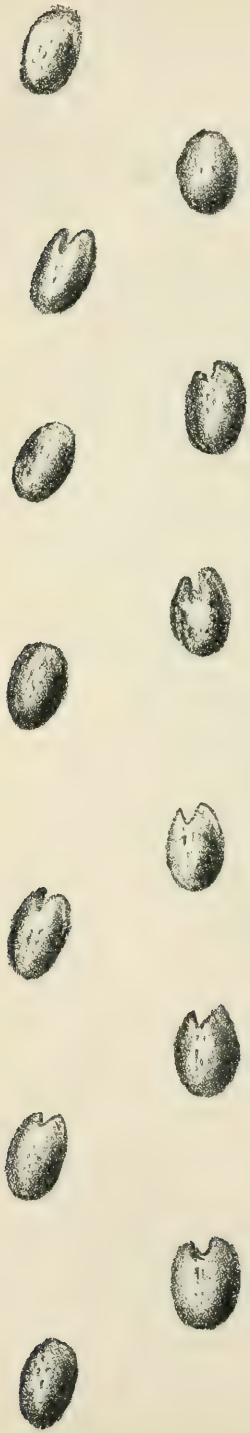
No. XII.—Note on the Occurrence of Footprints in the Calciferous Sandstone between West Kilbride and Fairlie. With a Drawing to Scale. By John Smith, Kilwinning.

[Read 14th November, 1889.]

On 12th June of this year, whilst examining the fine section of red Calciferous sandstone which is exposed in the cutting of the Ardrossan and Largs Railway, situated about two and a quarter miles north of West Kilbride, I was not a little surprised to discover a double row of what appeared to be the fossil footprints of some animal. When the cutting is entered from the south end a white post, with "$\frac{1}{4}$" painted in black figures on it, will be seen. The footprints are on the east side of the cutting, opposite the 102nd sleeper from the post mentioned. In other parts of the cutting there are also a few prints, but these are the best marked.

The sandstone at this point dips towards the east at the high angle of 80°, and the footprints are seen *in relief* on the under surface of the stratum of rock. The prints are in two rows, the right hand one showing six and the left hand one seven impressions, and they run in a S.W. and N.E. direction. No doubt if the rock was further quarried they would be found to continue for some distance more or less. The prints are all much of a size—about three inches long by two broad and half an inch deep. The spacings, measured from centre to centre of the prints, are, for the right hand row, 8, 8, 8, $7\frac{1}{4}$, and $8\frac{1}{2}$ inches, and for the left hand row, 8, 8, 8, 8, $6\frac{1}{2}$, and 8 inches respectively, and the lateral distances apart are from 6 to $6\frac{1}{2}$ inches from centre to centre. They are, of course, all pretty much abraded, having been exposed to the weather since the cutting was made some years ago, but are still very distinct, though the finer features are gone. They are roughly oval in outline, and some of them show a slight notch on what was probably the fore part of the foot, which in both rows inclines slightly inwards.

Mentioning the matter to Messrs. John Young, James Thomson, and other members of the Society, I found none of them had heard of footprints having been found so far down as the Calciferous sandstone. I also wrote our member, Mr. James Bennie of the Geological Survey, who from his position was likely to know the



"latest" in regard to such matters, and he, in his characteristic style, wrote at once—"In reply about footprints in the Calciferous sandstone, I don't mind of any, and if yours are four-footed you should ring the bells loudly at once, as we want much to get beasts with feet other than scorpions in that part of the formation."

Dr. Buckland, in his "Geology and Mineralogy," plate 26, figures some footprints from the New Red Sandstone of Corncockle Muir, near Dumfries, which he describes as "fossil footprints indicating the tracks of ancient animals, probably tortoises." They agree pretty much with the ones under consideration as regards size and lateral distance apart, but the "pacing" is altogether different.

Hugh Miller, in his "Fossiliferous Deposits of Scotland," printed at the end of his "Old Red Sandstone," page 367, says that the "footprints of a much larger reptile" (than *Parabatrachus colei*, Owen) have been "detected in our Dalkeith coal-field by Mr. Henry Cadell, the experienced and intelligent mineral surveyor to His Grace the Duke of Buccleuch."

At the meeting of the British Association of this year, held at Newcastle, Mr. T. P. Barkas read some "Notes on numerous newly-discovered Fossil Footprints on the Lower Carboniferous Sandstones of Northumberland, near Otterburn."

Much discussion has taken place as to the age of the Elgin sandstone, in which both footprints and remains of reptiles have for a long time been known, but as to whether the "balance of evidence" points to these rocks belonging to "Old Red" or "New Red," or to some other formation, I am not prepared to say.

The section in the railway cutting between West Kilbride and Fairlie, apart from the footprints, is well worthy of a

visit from the members of the Society. Nowhere could I point to a finer display of ripple marks, sun cracks, worm tracks, and rain pittings than are there to be seen. As the sandstone dips at the high angle of 80°, the railway at this part may be said to be bounded by inscribed walls. The sun cracks are magnificent, some I measured being eight inches long by five broad, and one, to one and a quarter inches deep. They were filled with soft red shaly sandstone. The ripple marks are of a great variety of sizes, ranging from three-quarters of an inch to three inches from ridge to ridge, and very distinct and sharp in outline, running in the different beds in almost every direction. Some have their ridges neatly shaved off, as if the beds had been moved in the deposition plane, probably during the time when they were being tilted to the high angle at which they now rest.

No. XIII.—Notes on the Excursion to the New Reservoir for Bowling Water Supply on 23rd March, 1889. With a Drawing. By W. J. Millar, C.E.

[Read 11th April, 1889.]

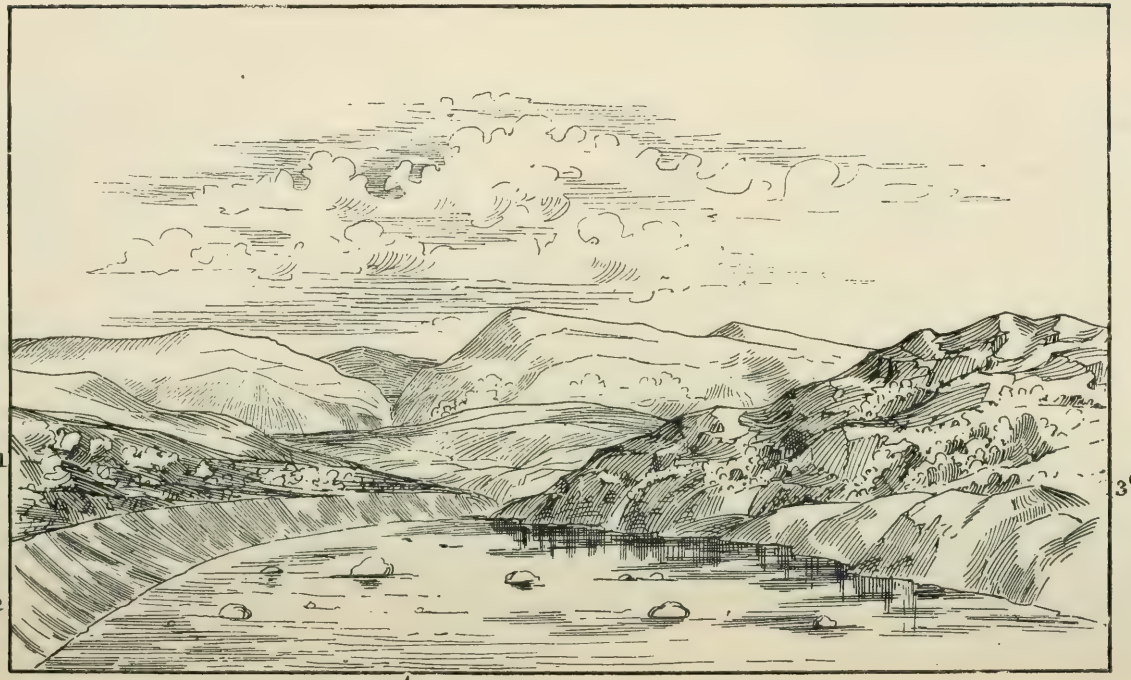
The Secretary having asked me to give a short description of the special features noted during the excursion, I may say that little need be said in regard to the Bowling district in general, as the members of this Society, from frequent visits to the well-known quarry, so rich in minerals, near the village, and to the glens in the neighbourhood, are quite conversant with the geological aspects.

The main object of the special excursion was to examine some well-marked glaciated rocks exposed during the excavation of the new reservoir just completed for the Bowling water supply, a few notes in connection with which may be of interest, and may serve to elicit information from members who were present or who may have made this interesting department of geological research their special study.

The site of the reservoir is at an elevation of about 600 feet above sea-level and about three-quarters of a mile to the north of the village of Bowling. A branch of the Auchentorlie Burn running through a hollow constitutes the feeder to the reservoir.

On the south-east side there is a rocky crest of trap very much weathered and broken up.

Reservoir for Bowling Water Supply—Looking East.



The ground to the north, north-east, and north-west is open moorland.

On proceeding with the excavation it was found that an abundance of clay could be got, and, throughout the whole work, even at depths from the surface reaching to fully 15 feet, nothing but clay was met with.

On removing the soil and excavating the clay on the south-east or rocky side, it was found that the rock changed from the irregular fissured and friable condition where it had been exposed, to a close, compact whin of a bluish shade, and gradually, as the clay was removed and the excavation proceeded, great bosses of finely-smoothed rock were exposed, with striæ running across the surface. It is needless to say that the rock *in situ* around Bowling is trap, or whin, as it is commonly called, several interesting varieties being found in the district.

In the clay itself great quantities of boulders were found—rounded, smoothed, and striated. These were afterwards broken up and used for the pitching on the water face of the embankment.

Had the weather on the day of the excursion been fine the members would have fully enjoyed a walk over this pitched surface, as it constitutes quite a geological museum of rock specimens.

As it was, those present, who from great experience were most capable of judging, were much pleased with what they saw, not only in the case of the finely-smoothed rock surfaces *in situ*, but with the varieties of rock which had been carried from a distance and deposited as boulders.

The glaciated surfaces face north-west and north, and from compass observations the action appears to have been from north-west to south-east.

The following are some of the varieties of rocks found as boulders in the clay. Doubtless some of those who were present will add others :—

Red or purplish sandstone.
Mottled sandstone.
Ironshot sandstone.
Quartzite.
Greywacke.
Mica schist. (Some specimens with pretty large flakes.)
Chlorite schist.
Porphyrite.
Amygdaloidal trap.
Dolerite.
Limestone.
Granite.

Since the date of the excursion I have noticed in the pitching a fine section of what appears to be hard sandstone with stems of plants. I am not aware if any of the members noticed it. I had no means at the time of detaching a specimen from it, but will endeavour to do so before the water (now rising in the reservoir) gets to it.

The clay throughout was stiff and of a reddish hue. Some bands of an orange colour were noticed.

Some of the members noticed traces of manganese in the rock *in situ*.

The upper portions of the rock indicated more of a tufa character, whilst the glaciated parts were close and compact. These latter parts were wholly covered by clay and soil, and are now, doubtless, for the first time laid bare since they were smoothed by the ice-sheet. The surfaces extend to about 14 feet in depth of slope, the inclination being something like that shown in the sketch on p. 204.

Doubtless much clay and many boulders still remain in the bottom of the reservoir, as no rock was met with.

Excavation for about 15 feet in depth was made through the clay and continued downwards for several feet more in the line of the puddle wall.

The party returned by way of Auchentorlie Glen, permission being kindly granted by the proprietor, Captain Buchanan of Auchentorlie, and inspections were made of the coal-beds situated near the foot of the glen.

[For an account of these coal-beds lying under the traps of the Bowling hills, see *Transactions*, vol. ii., p. 149].

No. XIV.—Journal of a Bore put down for Water at Thornliebank, Renfrewshire. With Notes on the Strata, by J. B. Murdoch, *Hon. Secretary.*

[Read 12th December, 1889.]

[Abstract.]

Mr. Murdoch said that the bore on which he now wished to make some remarks had recently been put down for water at the works of the Thornliebank Printing Company, Limited, Thornliebank, Renfrewshire, to a depth of 611 feet 6 inches. Through the usual alternation of blaes and fakes, thin beds of sandstone, limestone, and fireclay, the workmen struck first, at a depth of about 200 feet, a post of limestone nearly 7 feet thick, which he believed to be the Arden cement limestone, and, immediately below, a 17-feet bed of white sandstone. Then at 238 feet a heavy mass of sandstone in several posts was reached, its total thickness being above 50 feet, and probably representing the Giffnock sandstones. At a depth of 476 feet another bed of limestone, 7 feet 6 inches thick, was passed, probably the equivalent of the Cowglen, or Index limestone. No further strata of importance were afterwards met with, the coal seams passed through never reaching a thickness of more than a few inches. The object of the bore was not attained, no supply of water of any consequence having been met with, and the work was stopped at the depth above noted. Mr. Murdoch stated that as this bore was, so far as he could ascertain, the first which had been put down in this neighbourhood, he thought it was worthy of mention to the Society and of record in the *Transactions* for future reference.

At the close of the paper Mr. John Young, F.G.S., suggested that the failure to obtain a supply of water probably arose from the fact that the bore was put down near a fault which prevented the flow of water along the line of the strata. It might be found on further trial that a bore put down on the other side of the fault, if one really existed, would have a very different result.

Journal of Bore.

	Ft.	In.		Ft.	In.
Surface, Clay, and Stones, .	5	11	Brought forward, .	37	4
Dark Blaes, ...	8	4	Limestone, ...	1	1
Dark Fakes, . . .	4	1	Dark Blaes, ...	33	5
Dark Blaes, ...	19	0	Limestone, ...	1	4
Carry forward, . .	37	4	Carry forward, . .	73	2

	Ft.	In.
Brought forward,	73	2
Grey Fakes,	3	5
Limestone,	1	0
Fakes and Hard Ribs,	4	2
Limestone (Sandy),	2	4
Dark Fakes,	0	6
White Sandstone,	7	0
Fireclay (Fakey),	1	0
White Sandstone,	3	2
Parting,	0	3
Grey Sandstone,	4	3
Parting,	0	6
Grey Sandstone,	3	3
Fakey Fireclay,	5	2
Dark Sandstone,	6	3
Fakey Sandstone,	4	0
Sandstone, hard,	1	6
Sandstone,	2	6
Parting,	0	5
Sandstone,	2	4
Do., hard,	4	8
Do., softer,	4	7
Grey Fakes,	4	9
Dark Fakes and Ribs,	9	9
Dark Fakes,	9	3
Dark Fakes and Ribs,	3	3
Fireclay, coaly,	1	2
Dark Fakes,	1	5
Kingle Stone or extra hard Sandstone,	0	5
Fakes and Sandstone Ribs,	2	8
Dark Blaes,	0	10
Fakes,	0	6
Sandstone,	0	9
Do.. extra hard,	0	9
Fakes,	1	4
Sandstone, extra hard,	0	10
Fakes and Ribs,	7	8
Fakes,	3	0
Fakes and Ribs,	7	0
Sandstone,	1	0
Fakes,	0	9
Sandstone,	0	10
Dark Fakes,	7	0
Limestone,	2	7
Limey Fakes,	1	2
Limestone,	3	1
Fireclay,	0	11
Light Fakes,	5	3
White Sandstone,	17	1
Coaly Blaes,	0	5
Fireclay,	4	3
Fakes,	2	6
Sandstone,	0	8
Fireclay,	0	10
Do., Coaly,	1	4
White Sandstone,	49	3
Carry forward,	289	8

	Ft.	In.
Brought forward,	289	8
White Sandstone, extra hard,	3	9
Do., softer,	5	0
Fakes,	1	8
White Sandstone,	4	0
Do., extra hard,	1	6
Do., hard,.	4	0
Do., softer,	10	1
Fakes,	1	3
Sandstone,	37	5
Fakes,	0	9
Sandstone, hard,	1	0
Do., extra hard,	2	5
Do., softer,	2	2
Fakes and Ribs,	3	4
Fakey Blaes,	1	6
Sandstone,	0	6
Coal,	0	6
Sandstone, hard,	1	5
Sandstone Plies,	1	3
Sandstone, extra hard,	1	9
Fakes,	0	2
Fakes and Blaes,	5	6
Sandstone, hard,	7	5
Do., extra hard,	2	10
Do., hard,	2	11
Do., extra hard,	0	3
Do., hard,	0	7
Do., extra hard,	0	3
Do., hard,	0	6
Do., extra hard,	0	4
Fakes,	4	4
Sandstone, extra hard,	1	2
Fakes,	0	4
Sandstone, extra hard,	2	6
Do., hard,	1	8
Do., extra hard,	6	10
Do., softer,	0	8
Fakes,	1	9
Sandstone, hard,	1	2
Do., extra hard,	2	2
Do., hard,	2	7
Do., extra hard,	1	2
Do., hard,	1	0
Fakes,	0	4
Sandstone,	0	6
Fakes,	1	0
Sandstone,	1	4
Do., extra hard,	14	4
Do., softer,	4	6
Do., extra hard,	0	11
Do., hard,	2	4
Dark Fakes and Sandstone Ribs,	9	9
Dark Fakes,	19	11
Limestone (Arden),	7	4
Blaes,	1	0
Carry forward,	486	3

	Ft.	In.
Brought forward,	486	3
Sandstone,	1	5
Do., extra hard,	1	7
Do., softer,	0	10
Do., extra hard,	1	11
Fakes,	1	4
Sandstone, hard,	0	8
Fakes,	0	10
Sandstone, hard,	0	5
Fakes,	4	7
Fakey Sandstone,	3	11
Sandstone, hard,	0	6
Do., softer,	1	6
Do., extra hard,	1	3
Fakes,	2	5
Light Fireclay,	0	5
Dark Fakey Blaes,	1	8
Sandstone, hard,	5	8
Fakes,	3	7
Fakes and Blaes,	2	3
Hard Limey Rib,	0	8
Fakes and Blaes,	0	2
Sandstone,	0	10
Parting,	0	4
Sandstone,	0	8
Parting,	0	3
Sandstone,	2	2
Do., hard,	4	1
Do., extra hard,	1	1
Do., hard,	6	4
Carry forward,	539	7

	Ft.	In.
Brought forward,	539	7
Dark Fakes,	6	9
Sandstone, hard,	1	10
Do., extra hard,	1	8
Do., hard,	2	7
Coal,	0	5
Fakes,	0	3
Sandstone, hard,	4	10
Do., extra hard,	4	7
Fakes and Ribs,	2	11
Fakes, dark,	7	0
Sandstone, extra hard,	1	10
Dark Fakes,	1	9
Sandstone, hard,	1	3
Dark Fakes,	2	0
Sandstone, hard,	3	3
Do., extra hard,	2	9
Do., hard,	1	7
Sandstone, extra hard,	3	6
Dark Blaes,	2	8
Sandstone, hard,	1	9
Do., extra hard,	0	6
Dark Fakes,	6	9
Fakes and Sandstone Ribs,	3	0
Fakes,	0	2
Sandstone,	1	3
Fakes,	3	10
Sandstone, hard,	0	6
Fakes,	0	9
Total depth of Bore to 31st December, 1887,	611	6

This bore was executed by Messrs. John Henderson & Son, mineral boring prospectors and Artesian well engineers, General Terminus, Paisley Road Toll, Glasgow, between the months of August and December, 1887.

No. XV.—On Mammalian Remains from Cresswell Crag Bone Caves. By Professor John Young, F.G.S., *Hon. Member.*

[Read 13th March, 1890.]

The specimens exhibited are the first from the Cresswell district which have come into my possession. Several fragments are not yet identified, but those shown are sufficiently distinct. They are:—*Hyæna, spotted*, fragment of adult upper jaw; *Rhinoceros tichorhinus*, ulna; *Reindeer*, portions of two horns; *Horse*. For comparison I show the skull of a Hyæna from the Andersonian collection, and the difference of proportions will be seen by inspection.

The bones belong to that second stage of the Cresswell fauna posterior to the presence of the Hippopotamus. The caves have been described by Mello and Dawkins in the *Quarterly Journal of the Geological Society*, and a summary of the story is given by Dawkins in his "Early Man in Britain."

The traces of man in this region are of the cave man, and of the river-drift man, his predecessor and his inferior in cultivation. This order of succession is no doubt true for individual localities, the implements of the ruder people being found in layers below those in which the better shaped flints are found. But as yet the evidence of a race distinction between the two is unsatisfactory, and there is much in favour of Mr. Evans' view that the two men belonged to the same race and the same time. A singular flaw in the reasoning on this subject is betrayed in the oft-repeated statement that the cave man presented everywhere in Europe the same grade of civilisation, it being obviously assumed that each of the two peoples came on a distinct wave. It is further assumed that the duration of the Pleistocene age was of vast extent, and that thus there was ample time for the separate migrations. But this is a wholly arbitrary assumption. I shall immediately refer to the question of time. Meanwhile let me say that the passage of one race across Europe, be it from east or south, must have been gradual, and that as each horde moved from its ancestral home, mere lapse of time (not necessarily of *long* time) would add to the resources of the people. The gradual improvement of the conditions is a postulate of the Pleistocene history, and it is contrary to our belief in the capacities of the race that civilisation should follow epochs in time instead of conforming to the circumstances

which rendered improvement possible. But it is the time problem to which these interesting relics have tempted me to address myself for a few minutes.

As a zoologist I have long doubted the extreme antiquity usually assigned to palæolithic man, an antiquity which really rested on the ascription of each type of culture to its own epoch. Though not prepared to assert that man existed in Miocene ages, I have for several years taught that there is nothing inherently improbable in the supposition that negative evidence—that of the absence of his remains—was not conclusive. Sharing the belief that man migrated northward and westward from some more favourable nursery which, seventeen years ago I thought and still think, was in some tropical South Asiatic area, it seemed a necessary consequence that the pioneers were less civilised, less expert in the methods of comfort, than those who followed after them. In point of time, therefore, the western rudeness of life might be coeval with a better cultivated style of existence in the east. I had, therefore, not knowing of Mr. Evans' conclusions, advanced the opinion of the contemporaneity of the palæolithic and neolithic man. But what was then hesitatingly advanced, for the burden of great names (and let me add weighty censure of scepticism) was on the other side, was that this view forbade acceptance of the ancient doctrine that the first west European race had appeared eighty or a hundred thousand years ago. To have gained so much at so early a date, and to have stagnated for an immense lapse of centuries, was contrary to my zoological belief. Anatomy might require vast time (though I don't believe that either) for its modification, but that mental endowment, the capacity to improve his position by taking advantage of everything favourable in his surroundings, should be in abeyance for enormous periods, that seemed to be incredible and unsupported by trustworthy evidence.

It was therefore with great satisfaction that I read Professor Prestwich's paper in the *Quarterly Journal*, vol. xliii., and his more recent statement of belief in his great work on geology. Particularly admissible is his argument regarding the civilisation of the east, which, when we first come to know of it, 5000 years B.C., was already very high, and which, therefore, required a still more remote antiquity for its commencement. Prestwich does not think the limit of man greater than 20,000 or 30,000

years, and though he expressly says these are not precise figures, they represent fairly well a tangible estimate by which we can plumb the past. It is entirely in accordance with the views of those who accept the known facts of man's progress in historic times as proof of man's gradual improvement so long as he is in fairly favourable conditions. Shut in in a country enervating by reason of its tropical heat or numbing by its severe cold, there may be neither inclination in the one case nor opportunity in the other to struggle against his fate. What he has he keeps, and lives like a lotus eater in the tropics, or a semi-torpid machine on the shores of Greenland. But in Europe it was very different. There was everything to stimulate, nothing to unduly depress. Hence I have no hesitation in stating my belief that, for aught which has been asserted to the contrary, these bones and the men who saw their living possessors *may* have been the contemporaries of the incipient civilisation which, according to the latest researches, branched off to the north-east towards China, to the east to the Euphrates.

I append a note of the localities from which other specimens in the Hunterian Museum were derived :—

1. From the Kirkdale Cave. Specimens without precise locality given by Dr. Buckland to Dr. Brown of Lanfine.
2. From the Rock Shelter at Hunterston, given by Mr. Cochran-Patrick.
3. The Dusk Water specimens, given by Mr. John Smith, Kilwinning.

These are laid out in the Museum, and will well repay a visit by members of the Society.

No. XVI.—On Things New and Old from the Ancient Lake of Cowdenglen, Renfrewshire. By James Bennie, of the Geological Survey of Scotland.

[Read 10th October, 1889.]

For several years before I left Glasgow, in 1868, one of my favourite resorts for fossil-hunting was Gameshill, in the parish of Dunlop, Ayrshire. It was reached by railway to Crofthead, and thence by road through the pass in the Fereneze hills to Lugton, and onward by the Stewarton road—in all about 8 miles beyond the railway. The scenes passed on the way were often the chief attractions of my visits, the aspects of the hillsides and of the bright sheet of Lochlibo at the head of the glen, which varied with the seasons, giving me much pleasure at the time, as well as in after recollection when I contrasted them with the hard and dry scenes of my daily life in Glasgow.

In 1867 other attractions were, however, added. The glen had been chosen as the best route for a direct railway to Kilmarnock, and so through the workmen's operations became nothing more than a long quarry with all its uncouth sights and sounds. But my consequent anathemas were suddenly changed to blessings on the Fair Saturday of July, 1868, when I found the navvies busily engaged in cutting through a bed of clay and peaty mud, bringing back to the light of day the remains of a long-buried Lochlibo. This deposit had evidently been laid down in a deep lake formed by a ledge of rock which stretched across the glen and which the workmen had cut through before reaching the clay. Samples of this clay which I took showed plant remains. Hearing that the "forehead of an old cow" had been got in it 25 feet below the surface a few days previously, I called on Mr. Orchur, the overseer, who showed me what was really a skull of *Bos primigenius*. I took the following measurements:—across forehead, 11 inches; round base of horn, 13 inches; length of perfect horn, 30 inches; length of broken horn, 6 inches.

On 29th August I revisited Cowdenglen, chiefly because Mr. (now Dr.) James Geikie considered, as I learned from Mr. Croll, that the drift overlying the lake-beds was Boulder-clay as certainly as that the drift which lay below them was Boulder-clay. I then satisfied myself that, as the overlying drift was Boulder-clay (being full of striated stones, the best test I know of), the mud in

which the skull was found must be interglacial. I took a sample of the laminated lake-beds where they thinned out against the bank of Boulder-clay, finding it to be full of vegetable débris, such as stems of mosses and plants, and various seeds.

On 22nd October I again took samples of the clay-beds, giving portions to (the late) Mr. James Mahony, who found that about one-third of their bulk consisted of diatoms, the balance being largely remains of other organisms, animal and vegetable.

Again, in November, with Mr. Mahony and (the late) Mr. James Coutts, long a member of this Society, I paid another visit to the old lake, taking further samples, while Mr. Mahony sketched examples of crumpling in the lake-beds.

In December, 1868, I left Glasgow for Survey work in Edinburgh, and so missed a further exposure of the beds which took place in 1869, when a great landslip necessitated extensive excavations. But from reports sent me by various observers I was able to fairly follow the course of events.

In July, 1870, when on Survey work in Paisley, I made four further visits, one with Mr. R. L. Jack (now in Australia), taking fresh samples of the mud-beds, and finding a mammalian bone* lying under some of the beds still undisturbed, near the farm bridge over the railway between the two lakes, and near the western end of the east lake, in which bones of the elk, ox, and horse were found, as recorded by Mr. Robert Craig. This portion of the lake-beds consisted of layers of fine gravel and mud, about 5 or 6 feet deep, and it was evident that the bone which I found had fallen from one of the gravel layers. In these layers fragments of the upper peaty beds had occurred as waifs, and one of these I lifted and washed, finding in it several seeds identical with those in the solid mass of the upper peat-beds.

The first public notice of these lake-beds was given by Professor James Geikie (*Geol. Mag.*, Sept., 1868). Mr. Craig (Oct., 1868) expressed doubts as to the upper bed being Boulder-clay chiefly because it seemed to him to be lighter in colour and more gravelly than the lower bed, which was dark in colour, and compact and hard in consistence.

After heavy rain in the autumn of 1869 the mud of the lake-beds quickened and a landslip occurred near the north end of the east lake, bringing down part of the upper beds and the overlying

* See page 225, under *Mammalia*.

Boulder-clay, and disclosing the lower Boulder-clay standing up behind the lake-beds and between them and the rocky bank of the hollow. At first it appeared as if this settled the question as to the origin and character of the upper bed by showing it to be slipped stuff from the hillside above the hollow in which the clay-beds lay, and if that was so then Mr. Geikie's inference as to a second glacial period was wrong. In passing I may state that this theory dissipates entirely the doubts expressed by Mr. Craig as to the upper bed being Boulder-clay the same in origin and character as the lower one, but simply misplaced by landslips.

In the *Geological Magazine* for February, 1870, Mr. James Geikie discussed the landslip theory, and showed by diagrams that the gradients of the hillside above the hollow in which the lake-beds lay were such that it was impossible for Boulder-clay to slip down along them even to a small extent, far less bodily, as it must have done if it slipped at all, for there is now no Boulder-clay remaining on the hillside.

On 11th November, 1869, Mr. Craig read a paper to this Society (*Transactions*, vol. iv., p. 17), giving his final judgment on the whole question, and as he had the advantage of seeing the land-slips and the subsequent excavations I may quote the dimensions he gives of the upper Boulder-clay, the only one in dispute. "A small boss [mass] of it [the upper Boulder-clay] overlies the stratified beds on the west end of the western beds, and another small boss [mass] of it spreads over the divisional boss of lower boulder-clay, overlapping the ends of the stratified beds on both sides of it. . . . The small boss [mass] lying on the west end of the western beds has a length of 300 feet, and a thickness of 8 feet in its greatest depth. The other boss [mass], which spreads over the divisional boss of lower till and overlaps the end of the stratified beds resting upon it, has a length of 600 feet and a depth of 3 to 10 feet."

These "stratified beds" lay in two basins or hollows in the lower Boulder-clay, separated by a hillock of the same material, which had a length of 450 feet, and stood 8 to 10 feet above the upper stratified beds, stretching across the valley from side to side. The amount of the overlap of the mass of the upper Boulder-clay over the ends of the stratified beds is not given by Mr. Craig, but as the hillock of the lower Boulder-clay extended only 450 feet, while the upper Boulder-clay extended 600 feet, that gives

an overlap of 150 feet. Nor are we informed whether the upper Boulder-clay was equal on both sides, or whether there was more on one side than the other. Here, then, we have the testimony of Mr. Craig as to there being two masses of Boulder-clay lying upon the stratified beds, which could not result from a landslip, but only from regular deposition. He says that slips of Boulder-clay had taken place during the deposition of the lake-muds and peats in the eastern lake, but on reading his remarks carefully it will be found that these slips took place during the time when the lower half of the stratified beds in that lake were in the course of formation, and so have no reference to the upper Boulder-clay, which was a later and quite independent deposit made after the lake-beds were completed. This is clearly proven by what is said by Mr. Craig about the western lake-deposits, that they consisted of sand, gravel, and mud, the mud being very fine and entirely free from stones. The cutting into them was 15 feet in depth, but probably the entire depth was more than double that, while so far as the beds were seen, *no slips of Boulder-clay had run into them*, mixing itself with the soft mud, and in all other respects the stratified matter in it was identical with that in the eastern lake.

The source of the Boulder-clay which Mr. Craig speaks of as having slipped into the eastern lake during its earlier existence must therefore be sought for in the cliff of lower Boulder-clay which was found standing up between the lake-beds and the rocky wall of the hollow in which the lakes lay, and not in the hillside above the hollow, where, as Mr. James Geikie shows, there is now no trace of Boulder-clay.

As Mr. Craig's paper, though read in November, 1869, was not published till 1871, I had not the benefit of his observations when I visited Cowdenglen in 1870. The following extract from a letter which I wrote to Mr. James Croll on 16th July, 1870, will show that I had then arrived at the same conclusion as that which I have since drawn from a perusal of Mr. Craig's paper:—"From all I saw it was clear that the great noise made about the landslip of 1869 having set the matter to rest, by dispelling entirely the idea of a second glaciation, was much ado about nothing, the whole case, as I understood it before the landslip, being quite unaltered by it. Doubtless in some respects opposite the glaciated crag (at the north end of the eastern lake) the lower

Boulder-clay rises up from under the lake-beds and has formed the bank of the lake at that end, and from it slips may have taken place repeatedly during the existence of the lake, but that is all; the greater part of the cutting reveals what is undoubted Boulder-clay lying in a true position upon the lake-muds, and it was upon this Boulder-clay that all the conclusions were drawn, and they remain as solid and true as before. Such is the idea I formed from what I saw."

This is amply confirmed by the quotation I have made from Mr. Craig's paper, namely, that two masses of Boulder-clay, one 300 feet in length and 8 feet thick, and the other 600 feet in length and from 3 to 10 feet thick, lay upon the lake-beds, which Mr. Craig believes to have been deposited by water-borne ice at a period long subsequent to the final deposition of the lake-beds; and, of course, there can be little doubt that the lake-period was in times which we are accustomed to call interglacial. The only difference now between Mr. Geikie and Mr. Craig is that the latter believes the upper Boulder-clay to have been formed by water-borne ice or icebergs.

But if the facts given by Mr. Geikie and Mr. Craig are not considered sufficient to prove the upper Boulder-clay to be the result of deposition in the ordinary sense and not slipped stuff, there are other circumstances which place the lake and its peats and muds so close to the glacial period as to amount to contemporaneity with its later stages. These facts were briefly alluded to by Mr. Mahony (*Geol. Mag.*, 1869, p. 390), but what I suggested then to him I may repeat now, as it seems to me to be conclusive as to the extreme antiquity of the lake-beds and their contents.

As already stated, these lake-deposits lay partly on an earlier Boulder-clay, which was seen standing up as a hillock separating them into two basins and was also seen cropping up on the north side of the east lake; but on the south side of that lake the mud-beds lay directly upon and against a finely-glaciated surface of trap-rock, and upon that evidence of ice-action I found my argument for the extreme age of the lake and its silts.

On my visit in July, 1868, the most conspicuous, and to me most attractive, object visible was a cliff of dark red porphyrite on the south side, intensely glaciated, having on its surface small *roches moutonnées*, and striæ coarse and fine, its general surface

being highly smoothed and polished. A hollow indentation lay along the base of the cliff, and the projecting ledge above it was glaciated also. From the direction of the striæ, and, still more, from the southern faces of the small eminences on its surfaces it was clear at a glance that the ice which had glaciated this rock came from the south-west, that in passing down the glen it had encountered the ledge of rock which, from the base of the cliff, stretched across the glen, and that it had been dammed back by the ledge till it reached the top, when it passed over and escaped down the glen which slopes rapidly to Crofthead.

This glaciated rock-surface had been covered by the lake-mud up to a certain height, as was proved by portions of the mud found still remaining in crevices when I visited it. The upper part of the cliff and the hillside above it, which had not been protected by the lake-silt, were splintered and shattered through exposure to the weather.

Now, my argument for the antiquity of the lake and its silts is that if the base of the cliff had not been protected from the weather immediately after the final passing away of the ice it would in a very few years have lost, first the polish of the surface, next the finer striæ, and then the deeper ones. But even before the effacement of these had proceeded very far, the rock, especially at the overhanging part, would have cracked and splintered through the natural changes of the weather. This actually took place in the very short time which elapsed between the uncovering of the rock and the laying of the permanent rails, *i.e.*, two years or thereby. It follows from the fact that the drainage water of the glen, which, like the ice itself, would be dammed back by the barrier of rock, would rise to the same level that the ice reached, and would protect the rock from disintegration.

Thus we have proof that the lake was formed immediately after the passage of the ice, and of course the deposition of the mud would begin almost at the same time, and probably at first at a comparatively rapid rate, the drainage area being soft and without any covering vegetation. But afterwards, as the ground became firmer and more clothed, denudation by rain would be retarded and the deposition of mud would become slower, till finally the last stage would be reached in the formation of peaty sediment, one-third of the bulk of which consisted of the slowly-elaborated frustules of diatoms.

It may naturally be asked why I have allowed twenty years to elapse before offering these observations and exhibiting the various organisms found in these old deposits. As already stated, I washed some of the peaty silts in 1868 and early in 1869, and partially examined them, but feeling I could not make so much of them as Mr. Mahony could do, I laid them aside. In the summer of 1888 I learned that Mr. Clement Reid intended to trace the history of our present British Flora back into Pleistocene times, so I hunted up my old gatherings from various quarters and submitted to him everything which seemed to be of vegetable form or structure. In an admirable paper on the Pleistocene Flora (*Annals of Botany*, Aug., 1888) Mr. Reid catalogued eleven seeds as having been recognised by him in my Cowdenglen gatherings. I afterwards recovered some more of my gatherings of 1868 or 1870, and from them Mr. Reid has added twelve other seeds.

Besides the seeds other organisms were unnoticed by Mr. Mahony, and as these are interesting in many ways I thought that a re-statement of the circumstances of the discovery of the old lake and a catalogue of the old and new finds might be placed before the Society, not only to complete, so far as investigation has as yet gone, the life-phenomena of the old lakes, but also to show what may yet be done in a direction seldom taken—the examination and study of old inland lake-peats and silts.

As regards the organic remains found in these investigations, Mr. Mahony (*Geol. Mag.*, 1869, p. 390) gave the results of his minute examination of the lake-silts of Cowdenglen, in which he enumerated three species of desmids; thirty species of diatoms; eleven species of mosses; nine species of plants, represented by twigs, leaves, and seeds; one species of sponge, represented chiefly by spicules; one species of crustacea, represented by what seemed to be a larval form of *Daphnia;* thousands of fragments of clear yellowish animal tissue which he thought were the remains of a soft-shelled entomostracan; and many remains of insects, represented by numerous elytra and mandibles of beetles, of at least three species—in all fifty plants and eight animals, an exceedingly creditable number to be determined by one observer.

Next, Mr. Craig (*Transactions*, vol. iv., p. 17, 1871), besides *Bos primigenius*, first recorded by Mr. James Geikie, added *Megaceros Hibernicus* and *Equus caballus*, the first represented by part of a horn and the second by a few bones. He mentions, besides, eight

plants identified from branches, twigs, leaves, and bark, seen in his examination of the lake-beds, but of course he made no special or exhaustive search for such things as had been done by Mr. Mahony.

Lastly, Mr. David Robertson, in the lower clay beneath the peat-beds, found ten species of freshwater Ostracoda, as is recorded in the Monograph of the Post-tertiary Ostracoda of Scotland, (Palæontographical Society, 1874).

Mr. Mahony records that he found spicules of a freshwater sponge occurring frequently—indeed in every slide. As I did not examine the dust of my washings with a microscope I cannot say the same; but the objects Mr. Mahony supposed to be "the eggs of an insect, one of the ephemera," were pronounced to be the eggs of sponges by Dr. G. J. Hinde, who, in a letter to Mr. Reid says—"The bodies are the gemmules of freshwater sponges, otherwise known as the statoblasts or winter eggs. They belong to the two common species—the larger to *Spongilla lacustris*, Linn., which has smooth skeletal spicules, and curved spined acerate spicules of the gemmule — the smaller to *Meyenia* (*Spongilla*) *fluviatilis*, Auct., which are furnished with minute amphidisci, or spool-like spicules with radiate ends."

Subsequently, in a letter to myself, Dr. Hinde says—"I am glad to have the chance of seeing that the gemmules of freshwater sponges are capable of preservation in the fossil state, which, as far as I am aware, has not yet been recorded. The sponges themselves are disintegrated by the end of the season, and resolved into their constituent spicules; but the gemmules, being provided with an inner chitinous layer surrounded by a layer of spicules, are strong enough to endure transportation and preservation. There is hardly any difference to be noticed in these fossil minute spicules from those of existing species. They belong to the only two species of freshwater sponges which now occur in Britain, and it is very interesting to find them mingled together in the Cowdenglen material. The supposed 'midges' eggs' you sent last are really small groups of the gemmules of *Spongilla lacustris*. It is not at all uncommon to find them grouped in this manner, not unfrequently attached to the surface of stones, rocks, or pieces of wood."

A great number of round flat bodies which appeared in some of the washings seemed so like lycopod spores that I at first

supposed them to be such, and submitted them to Mr. Reid, but he, failing to recognise them, showed them to Dr. Hinde, who, by the assistance of Mr. Kirkpatrick of the British Museum, found them to be in reality the gemmules or statoblasts of a freshwater polyzoön, *Cristatella mucedo*, Cuvier. "This is," says Dr. Hinde, "a form which, according to Allman, is pretty generally distributed in England, Scotland, and Ireland. It is the only British freshwater form which has the statoblasts furnished with hooked spines, all the others being smooth. These statoblasts appear to be of a chitinous character like those of freshwater sponges, and they are similarly set free when the organism is broken up at the end of the season."

Such are some of the new things which I now wish to add to the record of Cowdenglen, and I hope they will justify this attempt to revive and increase the interest felt in these old lake-deposits, and in the times and conditions under which they were formed.

Those times and circumstances I may in conclusion briefly recall, as they were originally disclosed to us in the exposures made by the railway excavations, and in the examinations of the portions of the old lake-silts. In the lowest parts of the lake-deposits exposed we had a fine brick-clay, in which only clay nodules were noticed. In the clay immediately above occurred the ostracoda as recorded by Mr. David Robertson. Next came the lower peat-bed in which were the spicules and winter eggs of sponges and polyzoa identified by Dr. Hinde, also various seeds and mosses, with fragments of the chitinous coverings of *Daphniæ*. Lastly, the upper peat-bed in which were found other seeds and mosses and frustules of diatoms.

The times and circumstances represented by the different deposits consist, first, of the great glacial period, during which was laid down the lower Boulder-clay. Some writers think that this period was of short duration, simple in its course, and somewhat monotonous in its phenomena. A great sheet of ice covered the whole land to a great depth—2000 feet or more—in an unbroken mass, slowly moving outwards all round from the highest watersheds, grinding down the rocks it passed over, carrying with it all the débris made or gathered in its progress, and either dropping it here and there or delivering it at the ice-foot in a terminal moraine.

But was the glacial period short and simple in its course and

phenomena? I humbly think it was not, and that here in Cowdenglen, as in many other places, we have proof that it was long in time and varied and complex in its phenomena. The first proof that we have of this complexity is the diverse directions of the striæ in the district. Mr. James Geikie (*Geol. Mag.*, 1869, vol. vi., p. 74) says that further examination of the striæ had convinced him that instead of one set of striæ, as mentioned in his first note (*Geol. Mag.*, Sept., 1868), there are three sets. "The common direction of the ice-scratches in that neighbourhood is from about north to south, and the Lower Boulder-clay contains fragments of gneiss, mica-schist, granite, and other north country rocks. . . . The prevailing movement of the ice which deposited the Lower Boulder-clay must therefore have been from N. to S., but in the Cowden Valley there is evidence of a movement in the opposite direction. The knob of trap-rock, against which the *Bos*-beds have been deposited, is glaciated *down*, *i.e.*, north-east, and not *up* the valley as stated in my note. An older and much fainter set of striæ (the direction of which is not apparent, but may be either up or down the valley) are nearly obliterated by the later set; while on the north side of the valley above the railway cutting, and quite close to Crofthead, the rocks are glaciated *up* the valley, or towards the S.W. Similar appearances have been noticed elsewhere, showing that the ice-streams from the various centres of outflow sometimes prevailed the one against the other."

These striæ, pointing in opposite directions in exactly the same place, prove movements in the ice-sheet which were not simultaneous, but consecutive—a before and after movement. The cause of such changes is not manifest but conjectural, say, in a decrease in thickness of the ice-sheet, which allowed local gravitation to come into play, and lower hill-ranges to determine or divert the outflow of the lessened ice-sheet, which, when thicker, over-rode them. We may therefore infer that the south-pointing striæ on the hillsides above Cowdenglen were made in the earlier stages of the glacial period by a very thick mass of ice which, impelled by the force that drove it outwards from its centre of dispersion among the highest hills in the North Highlands, had an impetus sufficient therefrom which enabled it with ease to over-ride the Ferenezе hills, and pass out to sea over the lower grounds of Ayrshire. The striæ pointing N.E. on the glaciated crag on the east side of Cowdenglen were made in one of the later stages of

the glacial period by a lesser mass of ice whose centre of dispersion lay amongst the highest ridges of the Fereneze hills, and which flowing northwards down Cowdenglen passed into the sea over the lower parts of Clydesdale.

The lake-deposits prove a very great change indeed during the time of deposition of their 60 feet of thickness, and represent, in the varied character of the different beds and the organisms found in them, a lengthened period of time. The ice had passed entirely away, vegetation had entered and possessed the land, clothing the Fereneze hillsides with a flora as luxuriant as that of to-day, and capable of affording sustenance to at least three of the large animals of the latest Tertiaries:—The gigantic *Bos*, to which our Ayrshire kye seem dwarfs; the great elk with its regal crown of horns; and the small horse, of no great presence in itself but with capabilities of expansion into the big Clydesdale of to-day.

In the later lake-silts and peats, crowded as they are with stems and seeds of mosses, sedges, and pondweeds, with one-third of their whole bulk composed of diatoms, we see a long period of quiet typified by the present Lochlibo. In the upper Boulder-clay we have a return of glacial conditions, with ice again dominating land and water, spreading a drift-wrack of striated stones and glacial mud, in perhaps a fugitive and patchy manner, over the lake-beds and burying them from the light of day, till in these latter days they are brought to light by the railway navvy's pick and shovel.

Such is my story of the ancient lake of Cowdenglen as I now understand it, and I deduce from it a moral which I commend to the attention of my fellow-members of the Geological Society of Glasgow—"Put not off till to-morrow what can be done to-day." If I had taken advantage of the opportunities which lay to my hand in 1868 and 1869 of searching these old deposits as thoroughly as I have examined the remains from them still accessible to me in 1888 and 1889, the results would, I am confident, have been greater by a hundredfold than they now are.

Notes on Organic Remains from Cowdenglen.

Coleoptera. — Remains of beetles frequently occurred in the upper part of the lake-bed, but in a sadly disjointed state, though otherwise well-preserved. They consisted chiefly of elytra; but

limbs and segments of bodies also occurred. Mr. C. O. Waterhouse of the British Museum kindly looked over my gatherings, and said—"I feel sure many of the pieces might be identified by a coleopterist who has a little time to devote to them"; and of one form he remarks—"I feel sure it is a *Donœia*; at least I cannot think of anything else it can be, but we know of no species to which it can be referred." Of the others he recognised as follows:—

1. *Geodephagus*, probably *Pterostichus*, portions of elytra.
2. *Donacia*, sp.
3. *Auchemenus*, sp.
4. *Patrobus excavatus*, pronotum.
5. *Ilyleias angustior*, or closely allied species, pronotum.
6. *Acarus*, var. *falumnus*.

Caddis cases occurred, apparently belonging to four or five species, as they differed in the material of which they were built, and also in the style of architecture adopted. Some were built up of grains of sand imbedded in a network of pores, others had seeds and even pieces of beetles plastered on the outsides of the walls of the cases, and one was made up of vegetable fibres arranged like a piece of wattle-work.

Crustacea. — Though Mr. David Robertson has published ten species of ostracoda from the lower part of the lake-bed, which was composed of pure clay, none occurred in the upper part, owing, as he suggested, to the presence in the peaty silt of carbonic acid, which he found sometimes in quantity sufficient to redden litmus paper. This theory seems confirmed by the extraordinary abundance in this bed of the chitinous substance forming the coverings of *Daphnia*, which from its nature carbonic acid cannot affect. The quantity of these mica-like scales was so great sometimes as to cover the bottoms of my sieves to the thickness of a quarter of an inch. Thence we may safely conclude with Mr. Mahony "that the animals themselves existed in myriads during the deposition of the bed." Mr. Thomas Scott, naturalist to the Scottish Fishery Board, tells me that in silt similar to that of Cowdenglen, which he dredged from the bottom of Loch Ness at a depth of 129 fathoms, he found a like abundance of *Daphnia* scales. The epiphnia or winter eggs of *Daphnia* also occurred frequently in the same part of this ancient lake.

Mosses.—A good many fragments of mosses turned up in the

various washings of the upper silt-bed. Through the kind offices of Mr. Robert Kidston, F.R.S.E., they were submitted to Mr. Charles P. Hobbkirk, who has been able to determine four species, viz.:—

Hypnum cordifolium, Hidu.

Polytrichum subrotundum, Huds., or *P. aloides*, but probably the former.

Amblystegium serpens, Linn.

Brachystegium salebrosum, Hoffm.

Flowering Plants.—Seeds of the following twenty-eight species were determined by Mr. Clement Reid, F.G.S.:—

Ranunculus aquatilis, Linn.
Ranunculus flammula, Linn.
Papaver somniferum, Linn.
Viola, sp.
Montia fontana, Linn.
Rubus idæus, Linn.
Poterium officinale, Hook.
Hippuris vulgaris, Linn.
Myriophyllum spicatum, Linn.
Menyanthes trifoliata, Linn.
Pedicularis palustris, Linn.
Galeopsis tetrahit, Linn.
Ajuga reptans, Linn.
Polygonum lapathifolium, Linn.
Rumex crispus, Linn.
Betula alba, Linn.
Corylus Avelana, Linn.
Salix repens, Linn.
Pinus sylvestris, Linn.
Alisma plantago, Linn.
Potamogeton perfoliatus, Linn.
Potamogeton pusillus, Linn.
Potamogeton pectinatus, Linn.
Scirpus lacustris, Linn.
Scirpus pauciflorus, Lightf.
Carex rostrata, Stokes.
Isoetes lacustris, Linn.
Chara, sp.

Mammalia.—The bone referred to at page 214 was submitted to Mr. Simpson, assistant to Professor Turner, and he, by comparison with a skeleton in the Anatomical Museum of the University of Edinburgh found it to be the third left side rib of a horse not larger than a pony.

PROCEEDINGS FOR SESSION 1888-89.

(31st Session.)

Society's Rooms, 207 Bath Street, 11th October, 1888.

Mr. William Jolly, F.G.S., *Vice-President*, in the Chair.

Mr. Robert Dunlop exhibited specimens of Altered Intrusive Dolerite, the "White Horse" of the miners, from the Lanarkshire coalfield; also Plant remains from the Airdrie district, including *Cyclothea* (a new genus), *Lepidodendron Peachii*, *Cordaites*, sp., leaves and stem. Remarks on the dolerite were made by Messrs. John Young, F.G.S., Sommerville, Blair, F.G.S., and other members. It was stated that in mining phraseology altered columnar coal was known as "Black Horse."

Mr. James B. Murdoch, F.R.Ph.S.E., *Honorary Secretary*, exhibited a specimen of a rare fossil crustacean, *Prestwichia rotundata*, Woodward, found in Carboniferous Shale near Stevenston, Ayrshire. Unlike its congeners, the Trilobites and Eurypterids, this form is still represented in recent seas by the nearly-allied King- or Horse-shoe Crab. It has only been found previously in Western Scotland near Kilmaurs. Its occurrence in the present locality is another proof, if one were needed, that the fresh-water or brackish-water strata of the Upper Coal Measures are prolonged westwards. The Kilmaurs specimen was described and figured in the *Transactions*, vol. ii., part 3, page 241.

Mr. Dunlop said that when Mr. B. N. Peach of the Geological Survey was identifying some fossils from strata near Airdrie he had found and named an imperfect example of this rare limuloid form.

Mr. James White, *Honorary Librarian*, read a paper entitled "Notes on Gairloch, Ross-shire." [See p. 192.] The paper was illustrated by diagrams and by specimens of the rocks of the district. A discussion followed, remarks being made by Messrs. Dugald Bell, R. J. Steele, John Young, F.G.S., M'Lennan, and the Chairman. The latter said that, as the author had not exhausted the subject, he should give his further notes to the Society, and mentioned incidentally that the word "Archæan," as applied to the northern rocks, was unfortunate, as expressing finality, and that "Hebridean" was a much more appropriate and acceptable term.

The Chairman said further that, as he would not again occupy the chair owing to demission of office, he would take the opportunity of thanking the members for their appreciation of his occasional papers. He hoped that

the Society would continue to prosper, and urged the necessity of members making a continuous effort to increase the membership roll, which every year was being reduced by death and resignations from various unavoidable causes.

Society's Rooms, 207 Bath Street, 8th November, 1888.

(Annual General Business Meeting).

Mr. Dugald Bell, *Vice-President*, in the Chair.

The Honorary Secretary (Mr. Murdoch) read the Report of the Council for the past year. Mr. John Wight, C.A., *Hon. Treasurer*, read the Financial Statement, and Mr. James White, *Hon. Librarian*, submitted his Report on the Library.

Mr. David Forsyth, M.A., proposed that a hearty vote of thanks should be awarded the standing officials for their services on behalf of the Society. The motion was seconded by Mr. Joseph Sommerville, and unanimously agreed to.

The election of office-bearers was then proceeded with :—

Mr. Joseph Sommerville was elected Vice-President, and Messrs. William Armour, C.E., William Jolly, F.G.S., James S. M'Lennan, and Robert J. Steele, Members of Council.

Mr. Joseph Sommerville, *V.P.*, proposed, and Mr. David Forsyth, M.A., seconded a motion that the death of Dr. William Wallace, F.C.S., should be noted in the minutes, and that an expression of regret for his loss should be sent to Mrs. Wallace. Dr. Wallace had been for a number of years a member, and though this direct connection had latterly ceased, he had on several occasions contribut papers to the Society.

Mr. John Young, F.G.S., exhibited specimens and sections of a variety of Osmund Stone, a volcanic tuff, enclosing Pearl Sinter or Perlite, from Corrieburn, Campsie, and read some notes upon the subject.

Society's Rooms, 207 Bath Street, 13th December, 1888.

Mr. Joseph Sommerville, *Vice-President*, in the Chair.

Mr. William Cullen, teacher, 4 Catherine Street, N., and Mr. Duncan Macintyre, M.A., teacher, Cedar Cottage, Alexandria, N.B., were elected Ordinary Members.

The Honorary Secretary (Mr. Murdoch) read, on behalf of Mr. Robert Craig, *Cor. Member*, Beith, a paper entitled "Notes upon a Cutting in the New Kilbirnie Branch of the Lanarkshire and Ayrshire Railway on the Farm of Gurdy, Beith." [See page 64.]

At its close remarks were made by Mr. John Young, F.G.S., and Mr. James Thomson, F.G.S., the latter observing that a point of great interest referred to by the author was the great break in the succession of the strata, which extended through Ayrshire and Renfrewshire to the confines of Lanarkshire. Mr. Thomson said that Mr. Craig might be asked to extend his remarks upon the non-occurrence of the thick-bedded limestones

in the locality. He held that the igneous rocks of the district belonged to a period extending from the Lower to the Middle Carboniferous formations, and on this point the Geological Survey maps of the district were entirely wrong.

Mr. James S. M'Lennan read a descriptive paper on "The Geology of the Lugton Valley.' [See page 91.]

At its close an interesting discussion was taken part in by Messrs. Young, Thomson, Miller, D. Bell, and the Chairman.

Society's Rooms, 207 Bath Street, 10th January, 1889.

Mr. Daniel M'Millan, *Vice-President*, in the Chair.

Dr. Samuel Sloan, M.D., &c., 1 Newton Terrace; Rev. Alexander Simpson, B.A., B.Sc., F.G.S., 46 Princes Square, Strathbungo; Mr. William Brown, merchant, 22 Westminster Terrace; and Mr. James A. S. Little, M.A., teacher, Elgin Terrace, were elected Ordinary Members.

Mr. Walter Burns exhibited specimens of Intrusive Dolerite from Loch Ranza, and Sandstone with Dendritic Markings from John o' Groats, Caithness. Mr. D. C. Glen, F.G.S., exhibited a number of specimens of Sandstone, Slate, and Flint showing the same curious forms, and an interesting discussion as to their origin and occurrence followed.

Mr. John Young, F.G.S., exhibited, under the Society's microscope, several sections of a small hydrocoralline organism new to Western Scotland—*Mitcheldeania Nicholsoni*—found in limestone at Trearne, Beith. He said that it had been named *Mitcheldeania*, having first been found, by Mr. E. Wethered, F.G.S., in the limestone at Mitcheldean, in the Forest of Dean, some three years ago. It had now to be recorded as occurring at Trearne, Beith, Ayrshire, where it is found, somewhat sparingly, in one of the thin polyzoal bands of the limestone. Mr. Young described the minute structure of the organism, which somewhat resembles that of Millepora, one of the Hydrocorallinæ, but having smaller tubes and a more dense wall-structure than is found in the latter. Two species of *Mitcheldeania* have now been found in the Carboniferous limestones of Scotland, viz., *M. Nicholsoni* and *M. gregaria*, but the specimens exhibited are its first known occurrence in any of the western districts.

Mr. Matthew Blair, F.G.S., read a paper on "The Surface Geology of Paisley," [see page 139], illustrated by diagrams and specimens of rocks and fossils. A horn of *Bos primigenius*, found in the neighbourhood at a depth of 14 feet, was also shown. Remarks were afterwards made by Messrs. John Young, F.G.S., James Thomson, F.G.S., D. C. Glen, F.G.S., Steel, and the Chairman.

Society's Rooms, 207 Bath Street, 14th February, 1889.

Mr. Dugald Bell, *Vice-President*, in the Chair.

Mr. Henry M. Caddell, B.Sc., F.R.S.E., *Honorary Secretary* of the Edinburgh Geological Society, read a paper entitled "Recent Advances in the Study of Mountain-building, with special reference to the Structure of

the North-west Highlands." He explained that amongst most of the geologists who of late years had been engaged in investigating the structure of the N.W. Highlands, and especially those of them who did not concur in Sir Roderick Murchison's explanations of the phenomena exhibited there, there was a growing belief that great overthrusts had been largely instrumental in producing the remarkable stratigraphical relations of the rock masses of the region. It had therefore occurred to him and to some of his colleagues in the Geological Survey, after studying those great problems on the spot, that experiments might be made to throw light on the Survey work in the N.W. Highlands, by seeking to imitate in the laboratory the processes they believed to have been in operation at an early geological period. He had therefore begun a series of experiments based on such lines, which had been attended with great success, the resulting structures having a marked resemblance to those observed in the field.

With the aid of numerous diagrams, sections of strata, and geological maps, Mr. Cadell brought before the meeting the results of a number of the experiments he had previously made, and by the use of coloured sands and other materials he showed the remarkable results of pressure applied laterally to horizontal strata, which bore out to a wonderful degree his former theories on the subject.

Remarks on various points touched on in the course of the paper were made by the Chairman (Mr. Bell), who said that some of the remarkable structures he had met with on a visit to Switzerland last summer were distinctly explainable on the lines of Mr. Cadell's experiments, which were also, by Mr. John Young, F.G.S., pronounced to be admirable. Mr. William Jolly, F.G.S., stated that the problem of the N.W. Highland rocks, supposed to have been solved many years ago, had gradually become chaotic, but now its solution seemed to be proved with intellectual clearness. The lecturer of the evening had done more than any other man to render the subject of experimental geology comprehensive and conclusive.

Society's Rooms, 207 Bath Street, 14th March, 1889.

Mr. Joseph Sommerville, *Vice-President*, in the Chair.

His Grace the Duke of Argyll, K.C.B., was elected an Honorary Member. Mr. George M'Creath, mining engineer, 208 St. Vincent Street, and Mr. Robert Black, teacher, 18 Shaftesbury Terrace, were elected Ordinary Members.

Mr. W. J. Millar, C.E., made some remarks upon a locality of geological interest near Bowling, where he was at present constructing a reservoir for the Bowling Water Supply, and it was agreed that the members should make an excursion to it on Saturday, 23rd March. [For notes on the locality see page 203.]

The recent death of Mr. Matthew Blair, F.G.S., of Paisley, a member of the Society, was feelingly referred to by Mr. John Young, F.G.S., who moved that a vote of condolence with Mr. Blair's widow and family should

be passed. This was seconded by Mr. Dugald Bell and unanimously agreed to.

In a local paper an obituary notice stated that Mr. Blair was a successful man of business, and found in a moderate competence the reward of thrift, industry, and perseverance. But he was not altogether engrossed by the demands of his calling. He intelligently devoted a part of his time to scientific studies, and became known as a geologist of some standing. He was long a member of the Paisley Philosophical Institution, for some years convener of the geological section of that body, and at its last annual meeting was elected one of its vice-presidents. He was a member of the British Association for the Advancement of Science, the annual meeting of which he regularly attended; a member of the Geological Society of Glasgow, of which body he was for some time an office-bearer; and a Fellow of the Geological Society (of London). Some four years ago he formed one of the party of British Association members who went to the United States on a fraternal invitation from the *savants* of that country, and on his return he gave the members of the Paisley and Glasgow Societies some of the results of his experiences there. He was very familiar with the geological features of the neighbourhood of Paisley, and on various occasions he read descriptive geological papers to these bodies and contributed articles to the local newspapers. Mr. Blair took considerable interest in public matters, and in such improvements as the deepening of the Cart, of which he was an ardent advocate. He was long an office-bearer of the Abbey Close U.P. Church. He was a grandnephew of the poet Tannahill by the mother's side.

Mr. Robert Kidston, F.G.S., of Stirling, the well-known authority on Fossil Botany, read a paper "On the Fructification and Internal Structure of Carboniferous Ferns in their relation to those of existing Genera, with special reference to British Palæozoic Species." [See page 1.]

The paper was illustrated by a very large series of drawings and photographs, which were thrown on a screen by a limelight lantern.

At its close remarks were made by the Chairman (Mr. Sommerville), Mr. John Young, F.G.S., and by Mr. Thomas King. Mr. Kidston was afterwards proposed as a Corresponding Member.

Society's Rooms, 207 Bath Street, 14th April, 1889.

Mr. Daniel M'Millan, *Vice-President*, in the Chair.

Mr. Robert Kidston, F.G.S., Stirling, was elected a Corresponding Member.

Mr. John Young, F.G.S., and Mr. D. C. Glen, F.G.S., exhibited specimens and microscopic sections of a highly altered and decomposed White Dolerite intrusive in sandstone of millstone grit age, at Garngad, north-east of Glasgow. They explained the conditions under which the dolerite occurred in connection with the sandstone and a thin seam of impure coal, the dolerite being considered by the quarrymen a kind of pipe-clay. Along the line of contact both the sandstone and coal are seen to have been burnt and indurated by contact with the igneous rock; the

latter, although now much decomposed, still showing distinctly, in thin sections, the highly crystalline structure which it originally possessed.

Mr. JOHN YOUNG, F.G.S., exhibited a small slab of Sandstone from Giffnock Flagstone Quarry, near Giffnock Station on the East Kilbride Railway, the surface of which, in the space of 9 square inches, showed distinctly some twenty pairs of vertical burrows of a soft-bodied marine worm. These burrows are now termed *Arenicolites* from their supposed resemblance to the burrows of the recent lobworm—*Arenicola* of the present seas. Mr. Young then referred to the seeming great abundance of the group of soft-bodied ringed worms in the earlier arenaceous strata of the various fossiliferous formations, in the seas of which they must have swarmed. He further pointed out that those which inhabited a single burrow in the sand were termed *Scolithus* and *Scolecoderma*, and those which inhabited double burrows, like those exhibited, were named *Arenicolites*.

Mr. ROBERT DUNLOP exhibited specimens of Mineral Paraffin from Airdrie, where it is rare. It appears to be a product of distillation from oil-bearing strata at a time when they were exposed to considerable heat, probably from intrusive igneous rocks. Mr. Dunlop stated that a miner's opinion of it was pithily expressed when he said he thought it was "some of the creesh left about the time of the Flood." Specimens of the same mineral from Linlithgowshire were exhibited by Mr. Joseph Sommerville, *V.P.*

Mr. JOHN HOWAT exhibited two fine examples of Hematite from Cumberland—one of them mixed with crystallised barytes.

Mr. J. B. MURDOCH, *Honorary Secretary*, exhibited a portrait of the young Norwegian explorer, Dr. Frithjof Nansen, who, with five companions, had, last autumn, achieved the arduous task of crossing Greenland, and read some interesting details of their adventurous journey. He remarked that as Greenland was still in the grasp of a great ice-sheet, presumably somewhat similar to those which at one time or another had dominated our own country, Dr. Nansen's observations would be awaited by geologists with the keenest interest. From the fact that the party had been unable to reach the last steamer for the season, and had therefore been forced to winter in the island, only meagre details had yet reached us. He hoped on some future occasion to return to the subject.

Mr. MURDOCH then read some interesting notes (on behalf of Mr. W. J. Millar, C.E.) on the geological features observed in the excavations required for the new Bowling Water Works, and as seen by the members who visited the spot on 23rd March. When the Boulder-clay was removed, splendidly glaciated rock-surfaces were exposed, and the striæ showed that the moving ice had been forced straight up against the rock, which was lying at an angle of not less than 50 degrees. [See page 203.]

SOCIETY'S ROOMS, 207 BATH STREET, 9TH MAY, 1889.

Mr. DANIEL M'MILLAN, *Vice-President*, in the Chair.

Mr. WILLIAM DOUGLAS, quarrymaster, Golconda, Kilwinning, was elected an Ordinary Member.

Mr. Dugald Bell, *Vice-President*, read a paper entitled "The Phenomena of the Glacial Epoch: II. The Great Submergence." [See page 100.]

A discussion followed, and was taken part in by Messrs. John Young, F.G.S., William Jolly, F.G.S., H. M. Caddell, F.R.S.E., Steel, James Thomson, F.G.S., and the author.

Society's Rooms, 207 Bath Street, 30th May, 1889.

Mr. Dugald Bell, *Vice-President*, in the Chair.

Mr. A. B. Motherwell, Union Bank, Airdrie, was elected an Ordinary Member.

Mr. John Howat exhibited a large series of beautifully drawn diagrams of Foraminifera from the Chalk of the North of Ireland, prepared by Mr. Joseph Wright, F.G.S., of Belfast, an ardent worker in the field of microscopic geology. Mr. John Young, F.G.S., and other members spoke of the great value of Mr. Wright's researches amongst these minute forms of fossil organisms, and referred to him as an example of how much good work might be compassed in his leisure hours by a man otherwise actively engaged in commercial pursuits.

Mr. D. C. Glen, F.G.S., exhibited specimens comprising fine examples of (1) Geodes containing Crystals of Quartz and Calcite, from Iowa, U.S.; (2) Titanite or Sphene, from Renfrew, Ontario; (3) Specular Iron Ore, from Elba; (4) Geode of Chalcedony containing water, from Brazil; and made some explanatory remarks upon their occurrence and distribution.

Mr. John Young, F.G.S., read a paper "On a Peculiar Structure—Spines within Spines—in Carboniferous Species of the Productidæ." [See page 86.] In illustration of his paper the author exhibited under the Society's microscope several slides showing the arrangement of this hitherto unrecorded feature in the spines of this group of fossil Mollusca.

The Chairman briefly addressed the members on the close of the Session, during which some good work had been done, and hoped that they would all be spared in health and happiness to meet in the following October, bringing with them many objects of interest met with in their summer wanderings.

PROCEEDINGS FOR SESSION 1889-90.

(32ND SESSION.)

SOCIETY'S ROOMS, 207 BATH STREET, 10TH OCTOBER, 1889.

Mr. DANIEL M'MILLAN, *Vice-President*, in the Chair.

The CHAIRMAN welcomed the Members and hoped that the Session just commenced might prove no way behind any of its predecessors in interest and value.

Mr. ROBERT WOODBURN GILLAN, Indian Civil Service, The Manse, Carmunnock, was elected an Ordinary Member.

Mr. JOHN YOUNG, F.G.S., exhibited a fine series of specimens of Polyzoa and Monticulipora, comprising over 20 species, discovered by himself this summer at Kirktonholm, East Kilbride, in Carboniferous limestone shale. He explained that most of the specimens exhibited were extracted from blocks of shale which had been partly burnt in the kilns. The shale in its natural condition is of a dark blackish grey colour, but it changes through burning to a rock of a yellowish grey, the fronds of the Polyzoa being a brownish black, and their lace-like structure contrasting more strongly with the colour of the stone than when found in unburnt shale.

Mr. JOSEPH SOMMERVILLE, *V.P.*, exhibited a fine Quartz Crystal, with a Cavity containing Fluid, from the Calciferous Sandstone of New York State, U.S. Such specimens are geologically of great interest. Remarks on the subject of fluids enclosed in mineral cavities were made by Messrs. John Young, F.G.S., James Thomson, F.G.S., R. Dunlop, and other members.

The HON. SECRETARY (Mr. James B. Murdoch), on behalf of Mr. James Bennie, of the Geological Survey of Scotland, read a paper entitled "On Things New and Old from the Ancient Lake of Cowdenglen, Renfrewshire." [See page 213.]

The paper was illustrated by a map of the district, and by numerous specimens of animal and vegetable remains, some of the more minute forms being shown under the Society's microscope.

At its close an animated discussion was taken part in by Messrs. Young, Thomson, D. Bell, James Anderson, and other members.

Society's Rooms, 207 Bath Street, 14th November, 1889.

(Annual General Business Meeting.)

Mr. Joseph Sommerville, *Vice-President*, in the Chair.

The Honorary Secretary (Mr. Murdoch) read the Report of the Council for 1888-89. Mr. John Wight, C.A., *Hon. Treasurer*, read the Financial Statement, and Mr. James White, *Hon. Librarian*, submitted his Report on the Library. A cordial vote of thanks was thereupon unanimously passed to these gentlemen for their work on behalf of the Society. The following members were elected to fill the vacancies occurring in the Council at this time:—As Vice-President—Mr. John Young, F.G.S. As members of Council—Messrs. James Anderson, C. C. Bone, C.E., Daniel M'Millan, and David Ross, LL.D. Messrs. John Renwick and John Dougan were appointed Auditors for the current year.

Mr. John Howat exhibited a number of specimens he had recently obtained from the Triassic beds at Forth River, Belfast, including Variegated Marls and Fibrous Gypsum, on which he made some remarks.

Mr. James Thomson, F.G.S., exhibited a specimen, lent by Mr. James Miller, Canning Street, Calton, of a Fossil Fish, *Glyptolepis septopterus*, Agassiz, in a fine state of preservation.

Mr. John Wight, C.A., *Hon. Treasurer*, exhibited a specimen of Diatomaceous Earth from Skye, used commercially in the manufacture of dynamite.

Mr. John Young, F.G.S., exhibited a well-preserved cranial bone of a Carboniferous Labyrinthodont, which he had recently found imbedded in lower limestone shale at Braehead Quarry, near Busby. This bone, when compared with skulls of this group found elsewhere in the British coal-fields, seems to have formed one of the zygomatic or jugal bones of the skull of an amphibian reptile some 6 or 7 feet in length. The upper or exposed outer surface of the bone is ornamented with the same kind of grooved and pitted sculpturing as that seen on the skulls of the genus *Pteroplax*—one of the Carboniferous amphibians—teeth of which are recorded as having been found in this same locality. These lowly-organised amphibian reptiles are amongst the oldest of their class yet discovered, some five genera and seven species being noted from the Carboniferous strata of Western Scotland. They seem to have formed an intermediate link between the fishes and the true reptiles, having characters that are seen to be possessed by both of these groups. Their remains, which are very rare, are chiefly found in strata of freshwater or lacustrine origin, as they lived generally under aquatic conditions, and their footprints have occasionally been found impressed upon the muddy lake-shores of the period. The quarry at Busby in which this bone was found is the lowest geological horizon in which amphibian remains have yet been met with in the Glasgow coalfield.

Mr. James Thomson, F.G.S., also exhibited a specimen of a bone of the same reptilian character which he had found at the same quarry twenty-nine years previously.

Mr. Dugald Bell, *V.P.*, on behalf of Mr. John Smith, Kilwinning, read "Note on the Occurrence of Footprints in the Calciferous Sandstone between West Kilbride and Fairlie, Ayrshire." [See page 201.]

Society's Rooms, 207 Bath Street, 12th December, 1889.

Mr. Dugald Bell, *Vice-President*, in the Chair.

Mr. William Ker, 1 Windsor Terrace, Kelvinside, was elected a Life Member. Messrs. Matthew Blair, Merchant, 1 Hampton Court Terrace, and William Ernest Parker, Master, Middle-class School, Barnstaple, were elected Ordinary Members.

Mr. D. C. Glen, F.G.S., reported on the proposals made at the last meeting of the British Association in regard to Geological Photography.

Mr. James S. M'Lennan exhibited, from Cannibal Gorge, Reefton, New Zealand, specimens of "Petrified Moss" consisting of mineral deposits principally derived from heated waters strongly charged with lime and afterwards deposited on the vegetation which usually grew near hot springs; also specimens of Gold Quartz from the same neighbourhood. After some interesting remarks by Mr. M'Lennan, Messrs. John Young, F.G.S., Thomson, F.G.S., Glen, F.G.S., and other members spoke.

Mr. John Kirsop exhibited Sandstone containing dark patches, caused probably by the presence of metallic oxides, and showing curious concentric ring-like bands. The rock was said to be found *in situ* at Holywood, near Kirtlebridge, Dumfriesshire.

Mr. D. C. Glen, F.G.S., exhibited a series of Crystals of Minerals he had recently obtained from Cumberland Lake district. Amongst others were fine examples of Baryta, or Heavy Spar, Arragonite, Calcite in twin crystals, and Quartz, some of the latter crystals being unusually perfect.

Mr. James B. Murdoch, *Hon. Secretary*, read the Journal of a Bore recently put down for water at the works of the Thornliebank Printing Co., Limited, and read some notes as to the correlation of the strata met with. [See page 207.] Some remarks on the subject were made by Mr. John Young, F.G.S., and other members, an opinion being expressed that the reason water had not been reached was probably owing to the presence of a fault cutting off the continuity of the strata dipping towards the bore. If its position could be ascertained greater success would likely attend the sinking of a bore on its other side.

Society's Rooms, 207 Bath Street, 9th January, 1890.

Mr. John Young, F.G.S., *Vice-President*, in the Chair.

Mr. Robert Dunlop exhibited Jaws, Teeth, and other remains of Ganoid Fish from the Carboniferous shales of the Airdrie district, including several undescribed and rare species. The Chairman and Mr. James Thomson, F.G.S., spoke of their occurrence.

The Chairman (Mr. Young), on behalf of himself and Mr. D. C. Glen, F.G.S., made some further remarks upon the Tachylite rock found in the Old Quarry at Whiteinch in contact with the shales in which the fossil trees are there imbedded, and exhibited prepared sections under the Society's microscope. It was stated that since the period when their paper on this subject was communicated to the Society specimens of the various intrusive igneous rocks found in the quarry had been forwarded for examination to Mr. Frank Rutley, F.G.S., lecturer on mineralogy in the Royal School of Mines. The result of his microscopical examination and analysis has since been embodied in a paper read to the Geological Society, and printed in the *Quarterly Journal*, vol. xlv., 1889. The author there gives an interesting account of the minerals present in the different varieties of this rock, as also of the changes produced by the devitrification and weathering of the minerals themselves. It was pleasant to find that Mr. Rutley agreed with nearly all the statements made by Messrs. Young and Glen regarding the truly igneous character of the intrusive rocks found in Victoria Park Quarry. Mr. Dugald Bell, *V.P.*, Mr. James Thomson, F.G.S., Mr. Joseph Sommerville, and other members spoke upon the subject.

Mr. James B. Murdoch, *Hon. Secretary*, read, on behalf of Mr. John Smith, Kilwinning, a paper, on "The Great Ice Age in the Garnock Valley." [See page 151.] The paper was illustrated by a number of diagrams and sections. Remarks were afterwards made by Mr. Bell, Mr. Thomson, Mr. Murdoch, and other members.

Society's Rooms, 207 Bath Street, 13th February, 1890.

Mr. Dugald Bell, *Vice-President*, in the Chair.

Mr. Robert Dunlop exhibited, for Mr. Robert Linton, Kilmaurs, a large slab containing Reptilian remains from the Annick Lodge shale beds, probably one of the Labyrinthodonts, *Anthracosaurus*, with a length of from 10 to 12 feet. The head has not as yet been found. Mr. Dunlop also showed, for Mr. Andrew Sinclair, Kilmaurs, Carboniferous Plant remains from the Kilmarnock coalfield, including *Lepidodendron serpentigerum*, said by Mr. Robert Kidston to be the first Scottish specimen yet identified, and examples of various other ferns in their young, and fruiting, stages. Remarks on these exhibits were made by the Chairman, Mr. James Thomson, F.G.S., and other members.

Mr. James White, *Hon. Librarian*, read a paper entitled "My Ideas of 'The Great Ice Age,'" in which he reviewed the whole subject of glacial action in its various aspects, strongly supporting the views expressed by Dr. James Croll, F.R.S.E., in his well-known work, "Climate and Time." The paper was illustrated by a number of diagrams and maps. At its close a short discussion took place, but owing to the lateness of the hour was adjourned to the next meeting.

Society's Rooms, 207 Bath Street, 13th March, 1890.

Mr. Joseph Sommerville, *Vice-President*, in the Chair.

Mr. Robert Kidston, F.G.S., 24 Victoria Place, Stirling, was elected an Ordinary Member.

An adjourned discussion on Mr. White's paper on "The Great Ice Age," read at last meeting, was taken part in by Dr. Sloane, Messrs. James Thomson, F.G.S., James Miller, and other members.

The Hon. Secretary (Mr. Murdoch) read, on behalf of Professor John Young, F.G.S., notes "On Mammalian Remains from Cresswell Crag Bone Caves," recently presented to the Hunterian Museum. [See page 210.]

The Hon. Secretary also read, on behalf of Professor T. Rupert Jones, F.R.S., F.G.S., a paper, "On some *Estheria* and *Estheria*-like Shells from the Carboniferous Shales of Western Scotland." [See page 79.] At its close remarks were made by Mr. John Young, F.G.S., *V.P.*, who exhibited under the Society's microscope specimens of the fossils described in the paper.

Society's Rooms, 207 Bath Street, 10th April, 1890.

Mr. Dugald Bell, *Vice-President*, in the Chair.

The Hon. Secretary spoke of the excursions for the season, and remarked on a new feature on the card—a series of Friday evening excursions to easily accessible localities.

Mr. John Howat exhibited a fine series of photographs of Rock Sections taken in the North of Ireland, and remarked that he hoped members of the Society would follow the good example set by the Belfast Naturalists' Field Club, and record photographically many of the fine geological sections to be found in the West of Scotland.

Mr. John Young, F.G.S., *V.P.*, exhibited a Carboniferous Fish, *Uronemus lobatus* (?), Agassiz, in cannel coal, from Loanhead, Fifeshire. The specimen measures 9 inches in length, but is imperfect at head and tail. Its most interesting character is the numerous series of long tubular or hollow ribs that extend downwards and outwards in a brush-like manner along the central line of the body where the vertebral column must have existed, though not here preserved. The ribs are of a dense bony structure, their hollow interiors being now filled with a white carbonate of iron and lime. The scales have been very thin, circular in form, and are of a brownish colour, having a minute microscopic ornamentation on their surface as in the Coelacanthidæ, the group of fossil fishes to which this species belongs. *Uronemus lobatus*, with which Mr. Young was inclined to identify this specimen, was first described by Agassiz in 1843 from a specimen found in the Burdiehouse limestones. Since that time Dr. Traquair has described another larger species of *Uronemus* from the Upper Coal measures of Scotland, which he names *U. magnus*. It is also distinguished by its long dense rib bones and thin rounded scales. The specimen now

exhibited was sent by Mr. Kinnaird of the Edinburgh Geological Society, and was the first example Mr. Young had seen of this species.

Mr. Young also exhibited, under the Society's microscope, sections of a peculiar structure which he had recently discovered in specimens of *Fistulipora incrustans*, Phillips (*F. minor*, M'Coy). These sections showed the structure in a much finer state of preservation than those exhibited to the Society in 1883, when Mr. Young read some notes on this coral. Since that time he had always been on the outlook for specimens having the structure well preserved, only finding a few of the many he had prepared which well showed what he wanted. The structure seems to have been all very perishable, and to have disappeared in most instances either before or during fossilization of the coral. The specimens from Bowfield, Renfrewshire, were the only examples he had yet seen in which the spines were well-preserved within the walls of the corallites, but he had met with badly-preserved traces of their presence in one specimen from Roscobie, Fifeshire.

The perforated structure which Mr. Young discovered in the walls and sclerenchyma layers of the coral is fairly well-preserved in some of the examples found at Brockley, Lesmahagow, Trearne, and Dockra, Beith; but the finest example that has come into his hands was found amongst some fossils sent by Mr. James Bennie of the Geological Survey, obtained from shales on the banks of the Liddle Burn, Northumberland. In this case the coral was incrusting a stem of a crinoid. The section exhibited showed very distinctly the radiated structure of the walls of the corallites due to the slanting passage inwards of the pores or tubes that descended from the surface of the coral, where they appear as small acanthopores surrounding the corallites. These structures, which have not yet been figured in connection with this species of *Fistulipora*, have been examined with interest by Prof. Alleyne Nicholson, and now that it is known they do exist in all well-preserved examples of the coral it is hoped that a further look-out will be kept for them, and that they will be well illustrated and described in some future Monograph of the Carboniferous Corals.

The Hon. Secretary (Mr. Murdoch) drew the attention of members to the recent discovery of coal-bearing strata near Dover as one of great geological interest, the existence of those rocks in that district having been many years ago confidently stated by some of the leading geologists of the day, although others, notably Sir Roderick Murchison, denied that there was any possibility of their occurrence.

The Hon. Secretary then read, on behalf of Professor M. Forster-Heddle, F.R.S.E., St. Andrews, a paper, "On New Localities for Zeolites." [See page 72.]

Society's Rooms, 207 Bath Street, 8th May, 1890.

Mr. Joseph Sommerville, *Vice-President*, in the Chair.

Mr. Dugald Bell, *V.P.*, read a paper on "The Glacial Period: Recent Discussions and Progress," in the course of which he referred at some

length to the Duke of Argyll's address to the Royal Scottish Geographical Society.

A discussion followed, being taken part in by the Chairman, Messrs. John Young, F.G.S., *V.P.*, James White, William Jolly, F.G.S., and other members.

Society's Rooms, 207 Bath Street, 29th May, 1890.

Mr. John Young, F.G.S., *Vice-President*, in the Chair.

Messrs. John Chalmers, 14 Montgomerie Terrace, Mount Florida; T. Carter Parker, 3 Victoria Terrace, Dullatur; and Alexander Burrell, 227 West George Street, were elected Ordinary Members.

Mr. Joseph Sommerville, *V.P.*, exhibited a fine series of Graptolites from the Cambro-Silurian formation of the Levis beds at Quebec, Canada, and spoke of their occurrence and distribution. He also showed Plant Markings, and specimens of the rocks of the same district.

Mr. Robert Dunlop exhibited Carboniferous Ferns from Ellismuir, near Baillieston, including *Lepidodendron Jaraczewskii* (new to Britain), *Neuropteris acuminata* (new to Scotland), *Odontopteris Britannica*, *Cyclotheca biseriata*, *Unatopteris tenella*, and the latter in fruit.

Mr. James Anderson exhibited a number of fossils, including Fish Teeth —palatal, cutting, and petaloid, from the shales lying above the cement limestones of East Kilbride, which had been collected by Mr. Lindsay, successor to the late Mr. James Paton of that district.

The Hon. Secretary (Mr. Murdoch) exhibited a collection of Plant remains—stems, rootlets, &c., which he had found in freshwater clay overlying the Arden limestone worked near Thornliebank, and which had been washed out for him by Mr. James Bennie of the Geological Survey.

The Chairman (Mr. Young) read a paper "On the Internal Structure of the Carboniferous Corals forming the Genus *Chaetetes* of Fischer" [see page 57], illustrating it with a series of sections shown under the Society's microscope. Remarks on the subject were afterwards made by Mr. James Thomson, F.G.S., and other members.

The Chairman then declared the session closed.

Geological Society of Glasgow.

INSTITUTED MAY, 1858.

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Vice-President.

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TRANSACTIONS

OF THE

GEOLOGICAL SOCIETY OF GLASGOW.

No. XVII.—On Pectolite and Okenite from New Localities: the former with New Appearances.

By Professor M. Forster-Heddle, M.D., F.R.S.E., &c.

[Read 12th May, 1892.]

Two years ago, along with Mr. Harvie-Brown of Dunipace, I lit upon a hitherto unnoted locality where the modifications of basaltic structure are more varied than perhaps at any other in Scotland.

Basalt as a rule does not yield many of the zeolites, and this locality is no exception to that rule. It ultimately proved, after a fair search, that but two occurred—stilbite and pectolite; and of the former only a single specimen, and that a poor one, was obtained. The pectolite was, however, in fair abundance.

Dr. Macculloch describes how upon his first being able to evade the shore breakers, and to land at one of the zeolitic localities on the south shore of Skye, he found loose-lying masses of zeolite which had been dislodged by the weathering of the cliffs, and had fallen to the beach—fair evidence, he conceived, to his having been the earliest gleaner at the spot. The same was our good fortune at the locality I allude to. This is that part of Torosay in Mull which forms the north-west portal of Loch Screden, and the precise spot is the shore opposite to the rock called the Derag Sgeir.

The shore cliff is basaltic for some little distance on either hand of this; and, loose perched upon the summits of some of the

broken pillars, or lying amongst the comminuted and rounded fragments beneath, there were found several solid balls of zeolite.

These balls varied in size from less than that of a fist to more than that of a human head. When they departed in form from a nearly perfect sphere the departure exhibited a remarkable uniformity. This was the not unfrequent occurrence, especially in the larger balls, of a depression at one side, like that at the bottom of a bottle. The occurrence of several of these balls in position in the rock—some of a size greater than that of those found loose—showed that this depression was invariably at the base part of what had been a large steam vesicle ascending through a highly fluent magma.

The shape vouches in fact for an amount of fluidity greater than that which is disclosed by the form of the steam vesicles of the igneous rocks of Old Red Sandstone age in the Ochils; which vesicles have, in these rocks, by subsequent infiltration of silicious matters varying in colour and in substance, become agates.

These flows, as disclosed along a tract of country ranging from the Path of Struay to Partan Craig, had been so much more pasty than the basalt of Mull, that the steam vesicle assumed a balloon form, frequently with a sharp extremity, or even a silicified tag.

The white zeolitic balls collected from the Torosay shore proved of extreme toughness. While protruding portions could be broken with difficulty from the smaller masses by a swift blow of a light hammer, there was only one of the larger which could be fractured at the locality by repeated blows of a 12lb. hammer; and a mass little more than the size of two fists, when placed upon an anvil, only yielded to a 28lb. hammer after about thirty blows had been struck. The larger masses remain still unbroken.

This extreme toughness, and the structure disclosed upon the surface of fracture, left no doubt that the material was either pectolite or dysclasite (okenite), but the toughness was very much greater than that of any dysclasite which the writer had ever quarried.

The surfaces of fracture showed a multiplicity of mutually interfering, but hardly interlacing, groups of divergent crystals; these had a white or pale green colour.

This is so much the appearance of the pectolite of the West of Scotland,—whether found in veins in dykes, as at Manor House,

Oban, or in druses, as at Talisker Bay, Skye,—that doubt as to the nature of the mineral would not have occurred, and an analysis would not have been considered necessary, but for two circumstances.

The first of these circumstances was the appearance presented by the mineral in a cavity in the one large mass which yielded to the hammer at Torosay. In this cavity the mineral was distinctly crystallized, but the habit of the crystals was entirely different from that of the flat, scaly, transparent forms which occur at Ratho, Kilsyth, Bougang, and elsewhere.

Here they were in acicular divergent and rosette groups, such as scolecite and mesolite assume. From the centre of the cavity a detached ball, studded on every side with such groupings, fell out. Unfortunately the terminations and surfaces of these crystals, which are one-half to five-eighths of an inch in length, are rough and opaque.

The second circumstance which led to an analysis being made was the unique appearance of one of the smaller balls which had yielded to the hammer. This was also, unfortunately, a unique specimen.

The appearance was so precisely that which might be expected in a massive gyrolite, or in a druse solidly filled with gyrolite, that I had no doubt as to being able to determine the optic properties of that mineral on micro-sections cut from the mass. Large foliæ of pearly lustre, and a distinct "sea-green" colour, passed from all sides to the centre; generally these foliæ were flat, but here and there twisted and interwoven.

The cutting up the specimen with the diamond wheel, however, disclosed such extreme toughness and hardness as to throw doubt upon the specimen being gyrolite—specimens of undoubted gyrolite from the Treshinish Islands having been found, when being slit, not to be characterized by a hardness greater than that of most zeolites.

The slices cut thus with extreme difficulty were placed successively in the hands of three of the best micro-section preparers in the country, all of whom, after several trials, failed in supplying me with the smallest mounted fragment. The slices during thinning either crumbled through continuous fissuring, or sprang from the glass.

As a similar, and nearly as extreme difficulty, both as regards sectioning and thinning, is likewise experienced with pectolite, especially with what may be called *zeolitic* pectolite, it seemed to be possible that these substances might have some relationship to one another. This conjecture was fortified by the determination of their specific gravities, and by their blowpipe behaviour.

Supposed Pectolite.—Massive-fibrous, dull or glimmering. Gives strong sodium reaction. Fuses with difficulty to a white rough bead of glass containing small bubbles.

Sp. gr. on 327·4 grains, 2·763.
on 81·1 „ 2·742.
Hardness = 5.

Supposed Gyrolite.—Foliated, massive, pearly. Gives strong sodium reaction. Hence *not* gyrolite. Fuses to a glass clear while hot, becoming milky and enamel-like, but with bubbles, when cold.

Sp. gr. on 536·9 grains, 2·763.
on 66· „ 2·788.
Hardness = 5, or rather more.

This continued accordance rendered it necessary to analyse both; and Mr. Stuart Thomson, upon being applied to, very kindly agreed to associate himself with me in the enquiry, and undertook to make the analyses.

His determination of the specific gravity of the fibrous mineral was 2·736, which, with the foregoing, gives an average of 2·744; and of the foliated mineral 2·774, giving, with the previous determination, an average of 2·773.

The fibrous mineral yielded him as follows:—

Loss on drying, ...	·6
Silica, ...	53·74
Alumina, ...	·82
Lime, ...	31·19
Soda, ...	9·94
Potash, ...	none
Water, ...	3·38
	99·67

This is pectolite.

Of the foliated gyrolite-like mineral three analyses were made—two by Mr. Thomson, and one by Mr. Carr Robinson.

Silica, ...	53·41	52·95	53·39
Alumina, ...	1·76	1·71	
Lime, ...	31·69	31·48	33·41
Soda, ...	8·11	8·04	8·80
Potash, ...	2·42	2·42	
Water, ...	3·66	4·07	4·46
	101·05	100·67	100·06

Two other determinations of the water gave Mr. Thomson 3·71 and 4·21 per cent.

Mr. Robertson, in the determination of the water, got no loss at 150° Fahr., at a low red heat 3·5 per cent., at blowpipe temperature 4·46 per cent.

This is *pectolite* also.

The analysis of the first variety shows us that pectolite crystallizes in *acicular* crystals as well as in crystals of the usual wollastonite proportions; the second analysis evidences the fact that substances of identical physical appearances may have an altogether different composition; *the identity of appearance of this variety of pectolite with gyrolite is absolute.*

There was an observation of very considerable interest made at this locality by the writer; the locality was visited in two summers, and during the last visit he carefully checked the observation made upon the first occasion, drawing the attention of his companions to the circumstances.

Four or five of the larger balls of pectolite were quarried out of the basaltic pillars, which have an average width of less than 2 feet. Most of these balls occurred altogether within the pillars, but two—one in each summer—were wrenched by chisel and pinch out of *two* pillars; that is, the ball formed a connecting link or "key" locking the two pillars together, and crossing as a solid mass without exhibiting any rent, depression, elevated ridge, or observable mark the small space, say, a quarter of an inch or less, which lay between the two pillars.

What does this teach, or *seem* to teach? These balls are the solid plugs of steam holes; steam vesicles which were slowly rising through a viscous and slowly solidifying mass. After its

solidification they formed druses—tight cavities—which, upon the decomposition of the felspars, or of any nepheline which may have been in the rock, were, through the processes of endosmose and exosmose, filled, here solidly filled, with the zeolitic representatives of these altered components of the rock.

The "pillared state"—the rending of the flow into basaltic columns—must have taken place, not at the time of the solidification of the fluent or plastic mass, but after the endosmotic process had at least gone on to such an extent as to seal the cavity so perfectly that it had attained to the conditions necessary for the operation and continuance of the endosmotic process of transfer. Had the columnar rending taken place at the period of solidification, the rent which met the cavity would have permitted of the escape of the steam or gases, and the cavity would have been opened. It would indeed have been as open as the rents themselves—into which, as open spaces, no zeolitic matter passes, because there the conditions requisite for endosmotic action do not exist.

Seeing, however, that the rending, whenever it did take place, had neither opened the cavity, nor put an end to endosmotic plugging, it would appear that the rending had not taken place until the filling-up process was complete.

The above appears to the writer the only logical inference which can be drawn from the facts.

A corroborative, it may be said a fortifying, fact is the following. The writer has, in the northern wall-sided face of the most southerly of the islets of Inner Hyskier, seen a solid chalcedonic agate, of which one portion was in one of the pillars of pitchstone porphyry, while the other was in the opposite pillar.

The average dimensions of these pillars is about 8 inches in width. From one which was about 9 inches across the exposed face, he extracted the half of such an agate of zoned chalcedony, which was nearly 9 inches in length by 2 in thickness. The agate lay across the pillar with its rent surface on a level with the surface of the pillar. The shafted rock-face here plunges vertically into deep water: the rent agate was seen in passing in a boat.

Here it is evident that the contractile force of two pillars of 10 or 12 inches in width had been sufficient to cut by a clean rent,

not merely the rock-substance itself, but also some 12 square inches of solid chalcedony.

The fact that the intervening rents of a basaltic arrangement carry no zeolites, while the pillars themselves may have many amygdules is in itself a significant one. It has been said that scolecite occurs between the pillars in the roof of the Cave of Staffa. It certainly does not occur elsewhere in the islet between the pillars at accessible spots, and it is not easy to see how the recorder of the above statement got to the roof of the water-floored chasm. With a great deal of difficulty, and a great deal of help, the writer got nearly half-way up the side, and the white substance which he saw was of a pendulous form, protruding downwards from the general level, and spreading like a smear laterally for some distance over the surface of the rent columns. Broken columns in the island sometimes show upon their rent extremities a film of rock milk. Probably the so-called scolecite is only a calcareous stalactite; calcareous infiltrations are to be seen, though very rarely, between basaltic pillars.

The above observations thus seem to indicate that the rending of a lava flow into basaltic pillars did not, in all cases at least, take place as the immediate result of a chill from surfaces of contact, and that they did not so result was a contention firmly held by the late eminent naturalist, Professor Fleming of Edinburgh.

Dr. Fleming even went so far as to maintain that the rending was a comparatively recent process, and so much of a surface action, that if a number of pillars were removed from the exposed face the structure would gradually disappear and every appearance of pillar arrangement cease to be perceptible.

As directly bearing upon such a question, it has to be remarked that it is by no means the invariable rule (though it certainly is the general one) that the skrinkage rents which form the pillars proceed from the two surfaces of contact.

The writer has seen a dyke in the cliffy bank of the south shore of Sorvaags' Fiord in Waagöe in Faröe where the pillars stand parallel to its sides, while at the top of the dyke they radiate like costæ of a clam shell.

In the Scuir of Eigg there are at several points within its mass clustered groups of divergent pillars, which groups impinge in all directions upon each other.

Something of the same kind is seen in the semi-amorphous bed which overlies the colonnade at Staffa. And it is to be seen in a most marked manner in the vein of tachylite which cuts the basalt at the northern shore of the entrance of Loch Screden in Mull. Two localities can be mentioned by the writer where Dr. Fleming's contention seems to be borne out. The first is Balcarras Craig in Fifeshire, the second is a basalt dyke which crosses the Kinness Burn about a mile westward of St. Andrews. At both the process of quarrying is the removal of pillars—taking advantage in the quarrying of the absolute rock severance. At both the quarrying operations are abandoned intermittently on account of that rock severance gradually disappearing. At the Kinness quarry the severance more than once again became so evident and so open that the working was resumed. Doubtless this may to some extent be due to atmospheric agents developing and increasing the openness of a structure pre-existent though obscure; but it may also be due, at least to some extent, to a lateral relief of tension, and the actual recent establishment of rents.

Upon the writer's applying to Mr. Petheram, the road surveyor to the east of Fifeshire, that gentleman mentioned another locality where he had observed the same above-recorded facts—namely, the quarry at Faa Field, south of Drumcarrow Craig. He also stated that the quarry upon the south face of the Craig itself affords pillars for but a short distance inwards,—amorphous basalt, rent in every direction, succeeding.

The Ladeddie quarry, which is about 5 miles to the west of St. Andrews, may come to throw light upon this question. Magnificent clustered plumes of curved pillars are here seen. These lie in every direction; and so do not bear out any theory of contraction from cooling surfaces.

Such groups of pillars, when exposed in cross fracture during the quarrying operations, disclose rents of about an eighth of an inch between the columns. The dark-brown rock is seen to pass to pale green for a quarter of an inch round the margins of each pillar, and the intervening space contains transversely-fibrous pale green calcite. The dissolving of this by carbonated water leaves the pillars loose.

It is reasonable to expect that a rock pervaded by a system of

rents which resulted from the contraction of a micro-crystalline mass, would in microscopic sections disclose some modified arrangement of structure at those parts which were in contiguity to the surface of the rents.

The number and the regularity of the cross-fractures* seen in basaltic pillars at some localities led to the view being sometimes held that a system of flattened spheres was therein manifest.

Had the rending been the outcome of contraction in the direction of a multiplicity of centres, it may well be supposed that a certain amount of difference in the crystalline arrangement of the constituent minerals would be observed not only in contiguity to the rents, but even passing inwards towards the centres.

The writer found upon the east coast of Morvern, in Argyllshire, at a point about half-way between Loch Corry and Glen Tarbert, a small basaltic dyke, which fell asunder into a number of fragments like compressed grape-shot. These, however, when sectioned, showed no perceptible difference of structure in any part.

It should here, however, be remarked that some varieties of spheroidal structure which, either from being disclosed through a more rapid weathering of the intermediate parts, or from a difference in colour, are quite manifest to the eye, disclose no structure when examined by the microscope. This holds for the spheroidal clay slate of the Shiant Islands, as well as for the dolerites of the same islands, and of Morvern.

The microscope thus throws no light apparently upon the question. The facts, however, observed in the above-noticed quarries, taken along with the observations at Hyskier, at least call for a reconsideration of the views entertained regarding the dominant cause of basaltic structure.

Okenite.

Pectolite does not occur, so far as known, in either Greenland, Iceland, or Faröe: the non-sodaic okenite seems to take its place. The appearance of the two minerals is much the same, as is also the habit of their occurrence. Icelandic specimens of okenite show no other mineral associate. The same holds for the specimens from Disco. In Faröe okenite was found by the writer in huge balls imbedded in the channel of a stream near Tiornevig in Stromöe,

* *I.e.*, fractures at right angles to the pillar-faces.

and as a vein in Naalsöe at a point nearly opposite Torshaven. At both localities it was associated with no other zeolite.

Much the same thing is to be observed as regards the solitariness of habit of pectolite in Scotland. Though occasionally associated with other zeolites, such occurrences are very exceptional, and the quantity of these associates is small in relative amount. Very much the greatest quantity of the mineral occurs at Ratho, Lendalfoot, and Loch Screden; at the first of these localities it is almost always solitary, at the others invariably so. This statement as to absence of associates in the zeolitic druse applies only to the central portions or greater bulk of the cavity; for in many, if not in most cases of the occurrence of these minerals, a small amount of some other zeolite appears as a skin or first layer of deposition in the cavity. In the pectolite of the West of Scotland this layer is usually mesolite, rarely analcime; in druses filled with okenite it is usually heulandite.

Possibly the occurrence in Scotland of the sodaic variety of mineral may be explained by supposing it to be derived from labradorite (much the more common variety of plagioclase felspar in Scotland), and that okenite had resulted from the destruction of anorthite.

Still the evidence of the analyses subjoined goes to show, though not altogether satisfactorily, that okenite may occur in Scotland.

The first analysis was executed by Mr. Stuart Thomson, upon a specimen collected by the writer upon the south-west shore of Skye.

This shore is, except under the most exceptional circumstances, altogether unapproachable. With a south-west wind there lies no breakwater whatever between it and the Atlantic; with a south wind only the narrow width of Canna, distant 10 miles. The special danger of the coast is, however, due to the extraordinary distances to which great masses of rock have rebounded seawards in their fall from cliffs, which are at most points over 700, and in several attain to almost 1000 feet in height.

A maze of hidden danger has to be threaded; the altogether unexpected swell and break of a surf all around the boat has to be encountered; only upon two occasions has a landing been successfully accomplished at certain spots by the present writer. The almost immediate find of laumontite, altogether unrivalled, and of stilbite and heulandite, little inferior to that of Iceland, led him to

conclude that a like success, as regards landing and remaining on shore, could not have been attained to for a very considerable period. It was indeed with longing eyes that he had upon one occasion to hurry to the boat, leaving undetached a specimen of analcime with a surface of about one square foot, which was covered with pale blue crystals, nearly all of 2 inches diameter.

The locality at which the finest heulandite was obtained lies intermediate between Lochs Einort and Brittle. It is a short distance north of the mouth of the Allt Leth-uilt. Poor specimens of stilbite, and one—that analysed—of doubtful okenite, were found.

This specimen was exposed in a rock-face as the half of a filled-up druse; the other portion could not be found.

It did not seem to have suffered from surface alteration, and was altogether similar to the Stromoë okenite, having a faint tint of greyish yellow. It was imbedded in a soft, loose-grained, wackenitic rock, which is likewise the matrix of the fine heulandites and laumontites found on this coast. The rock is very similar to that which carries heulandite at Berufiord in Iceland.

At a promontory half-a-mile to the south, Dunan Earr an Sguirr, a second small loose fragment of the same substance was found; this was more like the Disco variety.

Of the specific gravity of the first I made three determinations, and Mr. Stuart Thomson made another.

Sp. gr. on	109·8 grains	2·174
on	69·8 ,,	2·209
on	64·6 ,,	2·189
Stuart Thomson	,,	2·219

Average, 2·198.

Hardness = 4·5. Of the specific gravity of the second I made one determination on 32·44 grains = 2·246.

	Mr. Thomson, obtained in the Allt Leth-uilt.	Dr. Heddle, Dunan Earr an Sguirr.
Silica,	48·28	54·22
Alumina,	4·14	·68
Lime,	30·63	27·22
Soda,	1·68	1·02
Water,	15·69	16·64
	100·42	99·78

As the zeolites of the West of Scotland have very frequently a thin outer layer of what has not inaptly been called "basement mineral," which the writer has by analysis determined to be a scolecite with some soda,—the sides of the portions analysed, as also those taken for the determination of the specific gravity, were all removed by slitting. The results of the first, and indeed of both analyses depart considerably from the composition of okenite; still the accordance as regards specific gravity, hardness, and water content are so close that they cannot well be separated from it, nor is there any other zeolite with which they upon the whole better agree.

Sections of the two specimens showed that from the promontory to be the purer; there seemed to be a little scolecite at the edges of the other, some crystals of which might have penetrated its substance.

The micro structure of the mineral differs considerably from that of pectolite. Like many pectolites it consists of spherical groupings of radiating fibres; but these fibres are of markedly greater delicacy than those of pectolite, and the mineral polarises in very faint colours, whether in thick or thin sections.

Optic Properties.

Lacroix and others have shown that there is very great difficulty in discriminating between such zeolites as assume an acicular divergent structure; the following notes on the general, and on the optic properties of pectolite, okenite, and similar minerals can be regarded as no more than a contribution towards our knowledge. Such optic properties as are disclosed by the very unsatisfactory sections which (on account of the bitterness of these minerals) can alone be obtained, suffice, however, when taken along with their general structure, for their discrimination from each other in sections ordinarily obtainable; while they also suffice for the discrimination of the pectolite of Manor House from tesselated apophyllite, and of all the named minerals from stilbite.

Pectolite.—This occurs crystallized in Scotland at Ratho in Edinburghshire, at Kilsyth in Stirlingshire, and at Knockdolian in Ayrshire. All attempts which I have made to bring crystallized portions into a section have failed on account of this, that, however tough the fibrous portion may be, the crystals invariably break away.

As a rule, pectolite is very difficult to work to a section—tending to split, and still more, to spring from the support. I have only succeeded in getting sections from Ratho; Gloom Quarry in the Ochils; Manor House, Oban; and Loch Screden in Mull.

The appearances seen in the Ratho mineral are typical of the others, with the exception of that from Oban. The characteristic feature is that, however thin the section, everything is seen as through a haze—colours and structural markings being alike dulled and blurred.

According to the angle at which the slitter has sectioned the fibres, the structure is lanceolate, or is engine-turned. Of the Ratho mineral the colours are dull green and red, with crossed Nicols; and the dark cross under crossed Nicols is very seldom seen on account of the large size of the divergent groupings. If the section is turned 45° the colours are yellow, purple, and orange. With the analyser set at an angle of 45° to the polariser, that which usually appears as a dark cross is still apparent, but it and the colours are alike pale.

Pectolite of Manor House, Oban. A thin vein in dolerite. Stuart Thomson found the amount of water in this to be 3·52 per cent. This shows a confused, matted, and divergent structure in its general mass. The colours, somewhat clearer than those of most pectolites, at vanishing thinness disappear, or pass to blue-grey or to darkness. Throughout this there lie, nearly parallel to the sides of the vein, comparatively large crystals, which, with crossed Nicols, obscure parallel to their length. With parallel Nicols they are colourless.

When turned 45° from the point of observation, with crossed Nicols, the crystals have an orange colour at vanishing thinness; and at the same point with parallel Nicols this changes to a brilliant blue and a deep blue.

Many of these larger crystals show a tesselated structure. This consists of a single line of rectangular tesselæ, which do not generally cross the whole width of the crystal. With crossed Nicols and the crystals set at 45° from the line of observation, these tesselæ are alternately orange and dark blue, becoming in the same position with parallel Nicols pale blue and lemon yellow respectively. They are thus altogether different from the tesselæ of apophyllite.

With ordinary light the crystals are seen to be irregularly cross-barred by lines of dark dust. The tesselæ are sometimes defined by these lines, but are in no way dependent upon them—some barred crystals showing no tesselæ, and some without bars showing many, while bars cross the tesselæ themselves.

Wollastonite. Glen Urquhart.

Near the Free Church at Newton, Glen Urquhart, Inverness-shire, a vein of white fibrous wollastonite cuts a rock chiefly composed of hydrous anthophyllite, biotite, and diallage (?).

The writer determined its nature by analysis.

	1.	2.
Silica, ...	49·142	49·065
Alumina, ...	·617	·601
Ferric Oxide, ...	tr.	—
Lime, ...	43·7	43·01
Potash, ...	·634	1·008
Soda, ...	2·957	2·728
Water, ...	3·027	3·098
	100·077	99·510

Structure, massive-fibrous. Colour, skim-milk. Excessively tough. Sp. gr., 2·715. In appearance it is so like pectolite that its optic properties are inserted here.

It has a lozenge-like structure, delineated in pale brown tints. This is not due to the crossing of fibres from the opposite sides of the vein, as the acute angle of these lozenges is very much less acute than that of the diverging tufts of crystals, which indeed the lozenge structure crosses. Moreover, the structure is evident even up to the margin upon both sides.

Being an exfiltration vein, the crystalline tufts would grow from both sides. The more marginal portions having become solid structure before the fibres from the opposite side had reached the centre of the vein, these latter could not intersect them so as to form any such lozenge structure.

Xonaltite.—Geo da Tuill, Loch Einort, Skye; also Loch Brittle, Skye.

Shows both dark and pale blue, *under all treatment.* Had a very minute spicular structure.

Tobermorite.—Scuir nam Boc, Loch Einort, Skye.

Has a large plumose structure : the tufts are quite independent of each other in their offsets, but are thereafter interwoven with each other. Very arborescent and branching. Blue and yellow colours appear together ; these at vanishing thinness disappear, the section showing then only light and dark. The crystals seem to obscure parallel to their length.

Okenite.—Vein, Naalsöe, Faröe.

Obscures parallel to fibres. Blue and colourless seen together, very little yellow. Yellow dominant with parallel Nicols. The structure is very minute.

Tiornevig, Faröe. Solid druses.

Obscures parallel to fibres. Yellow to colourless with crossed Nicols. Blue passing to brown with parallel Nicols. At vanishing thinness with crossed Nicols is colourless to pale blue. Has a tufted structure, but not so much branched as tobermorite. Specimens from Bordöe, Faröe, are altogether similar.

Disco, Greenland.

More like the radiations of mesolite, but it could not be sufficiently thinned.

Loch Einort, Skye.

Is very similar to that of Naalsöe.

Loch Brittle, Skye.

Has finer fibres, and these radiate from a greater number of centres. This looks more like an intermediate with pectolite.

Mr. Stuart Thomson has sent me the results of an analysis which he made of specimens of the pectolite which I forwarded from Manor House, Oban.

Sp. gr., 2·734

Silica, ...	54·63
Alumina, ...	4·56
Lime, ...	26·68
Soda, ...	10·69
Potash, ...	tr.
Water, ...	3·92
	100·48

He remarks—"This high percentage of silica seems to be characteristic of the pectolites of the West of Scotland."

No. XVIII.—The Late Sir A. C. Ramsay, F.G.S., Director-General of the Geological Survey of Great Britain. By John Young, M.D., F.G.S., &c., Professor of Natural History in the University of Glasgow.

[Read 14th January, 1892.]

The life of Sir Andrew Crombie Ramsay is of very special interest to Glasgow geologists. Born in our city seventy-seven years ago, he owed his start in the career which led him to fame to the share he took in the work of the meeting of the British Association in Glasgow in 1841. But the impulse toward science was of much earlier date. His father was associated with the chemical industry of Glasgow, not merely as a successful manufacturer, but as an inventor of processes which made the production of bichromate of potash and pyroligneous acid commercially remunerative. To home influences was added that of John Pringle Nichol, Professor of Astronomy in the University. Nichol was a man of remarkable power as well as genius. It has been said that genius means an infinite capacity of taking pains. Nichol's genius had little to justify that definition. He was essentially a poet, gifted with marvellous instinct for the meaning of scientific facts, and by virtue of his poetic gift capable of conveying to others in extraordinary fashion his sense of the inner meaning of what he had learned. Ramsay used his skill as a draughtsman in the illustration of Nichol's "Architecture of the Heavens"; and though in after years he had learned how unreliable Nichol was as a guide to facts, he ever owned with enthusiasm his great debt to one who had given him a love for science by showing him the grandeur of the generalisations to which its study might lead. It is, indeed, not too much to say that the West of Scotland is still under obligations to that forgotten genius, neglected because he was not always accurate, yet powerful, perhaps because he was not accurate, in rousing interest in science where there had been ignorance, enthusiasm where previous efforts had been laborious but narrow.

The Andersonian University Museum still contains the model of Arran which Ramsay prepared for the Association meeting of 1841, and it indeed deserves the name of a model. As a monument of its author's clear recognition of geological facts, of his capacity for inventing his own methods, of the intuition by which he arrived at

the essential facts of geological surveying without teacher or guide or example, the model of Arran is, and will ever remain, a valued possession of the Technical College, and the copy in the halls of the Jermyn Street Museum will long keep green the memory of the self-taught geologist. For the work has to be measured, not by the knowledge of to-day, but by the ignorance of the time when it was done. Lyell's "Principles" began to be published in 1830; but the importance of what we now call historical geology had been tardily recognised, so tardily that the "Elements of Geology" was not published as a separate treatise till 1838. Prior to that time Scottish topographical geology had been largely mineralogical; and it is no small proof of Ramsay's power that his work on Arran was simultaneous with the publication of Maclaren's "Geology of Fife and the Lothians," a valuable memoir which owed much to the teaching of Jamieson and to the sympathetic rivalry among his disciples. These aids were not available to the Glasgow geologist, who had to teach himself the art of surveying and to discover the method of geological description. The apprenticeship thus served was laborious, but its fruits have been of the highest value to British science, for no school could so well have prepared for his duties the future head of the Geological Survey. Yet that position was only accidentally rendered possible. Murchison had been greatly impressed by the work of Ramsay, and invited him to share an American tour which he had contemplated. But the Russian expedition with von Keyserling and De Koninck had superior attractions, and Murchison, who had, before his change of plans, taken Ramsay up to London, secured his engagement under Sir Henry De la Beche, who had already begun the Local Survey, which he dexterously converted, almost without the knowledge of the ministers whom he made his associates, into a National Survey. Ramsay joined Sir Henry at Tenby, and the association was a most fortunate one. De la Beche has scarcely had justice done him. The pedantry of the Prince Consort could only see narrow-mindedness and the domination of one idea in the tacit opposition De la Beche showed to "the milky mixture of science and art" which now wastes so much of the money and time of the country in teaching which is not education and manipulation uninspired by art. De la Beche had far wider views than those patronised by the Prince and obediently applauded by

some who have since grown to honour thereby. A man of wide culture and of great artistic taste, accurate beyond the wildest dreams of contemporary geology, bold yet cautious in reasoning, and endowed with that great literary gift which makes simple unadorned English interesting and even eloquent, he found in Ramsay an apt pupil and a congenial associate. Descriptive geology was the aim of Sir Henry. He had to earn an extension of his scheme by proving its economic value; and thus the philosophic study of geological processes received only as much attention as could be spared from due attention to mining industries. Those who have read De la Beche's "Geological Observer," especially if they have read it early in life, will bear witness to its fascination. One feels that he is reading, not a scientific treatise, but his own views and observations; and the everyday character of the studies detailed is enhanced by the pictorial illustrations which Sir Henry's fine taste substituted for the crude diagrams of his predecessors and contemporaries.

Under such a chief the best qualities of his subordinates were elicited. When Ramsay joined he found himself in a brilliant company of young men, who afterwards earned distinction—John Phillips, Captain James, David Williams, Warrington Smythe, and later Edward Forbes, Oldham, Jukes—all men of ability, culture, scientific enthusiasm, and genial character. It is difficult to fancy a more fascinating life than that of the early surveyors. Field-work at that time in the lovely scenery of South-West England—field-work during the day, in the evening comparison of notes, discussion of views, and lively talk, made life seem one long holiday. How much more must it have so seemed to a Glasgow man who had plenty earnestness at home, but who not merely found, to his surprise, that earnestness and fun were compatible, but discovered that the best work owed something to the combination. In 1846 appeared his memoir on "The Denudation of South Wales and the adjacent Counties of England," a memoir which proved the capacity of its author as a careful observer, and still more his power as a thinker, whose boldest influences were ever found to rest on a solid foundation of demonstrated fact. The treatise was curiously modelled on the style of his loved chief, whose memory, carelessly held by his country, lives best in the history of British science as

the founder of field geology. It was perhaps a misfortune in the long run that the Geological was so closely linked with the Ordnance Survey. Yet it had its advantages in the accurate mapping which had become habitual before the two departments were finally severed. Few, nowadays, have any conception of the hindrances in the way of field geology nearly fifty years ago. The difficulties of transport were considerable; there was not even the cultivated slowness of a Cambrian railway; accommodation was of the simplest, and not always to be had; while maps were by no means at command nor of the scale which facilitated work. To this last circumstance is perhaps due the copiousness of the notes necessary to explain the brief signs on the maps, the detailed records thus compelled becoming a valuable tradition in the Survey. Meanwhile the service assumed greater importance, and with it greater dimensions. Ramsay was in 1845 appointed Local Director for Great Britain, Captain James for Ireland, Sir Henry being Director-General. In 1848 he was appointed Professor of Geology in University College, and marked his entrance on the duties of a teacher by a masterly history of geology. In later years he was wont to impress on his staff the duty of keeping clear in their minds the work done by earlier writers; he rightly maintained that this was an obligation of gratitude which would be rewarded by the mental training it involved. In obedience to his principle, he examined the systems of earlier writers, and his comments are remarkable for a man of thirty-four who had spent so many years in business and later in field-work. The thinker and the observer were rarely combined. To the early Survey days belongs the remarkable anticipation of much later work in the reference of the Old Red conglomerates to ice-action. No doubt it has been overdone by other writers, and the facts, which are few, have been tortured into proofs of recurrent glacial epochs, a kind of speculation which Ramsay certainly would not have encouraged. Ice had an attraction for him; he spent time in the Swiss Alps; he visited America in 1857, and afterwards wrote on the Glacial Phenomena of North America, which he had examined in the company of his old colleague, Sir W. Logan, and of Professor James Hall. "Peaks, Passes, and Glaciers" contained a paper by him which was afterwards published separately under the title, "Old Glaciers of Switzerland and North Wales." This volume is

still of great value, for it did what Ramsay thought should be done for all formations, it endeavoured to restore the scenery and geography of the past. The pencil which illustrated the "Geology of Arran" with picturesque vignettes was utilised in the portraiture of Welsh scenery as it is, and the restoration of the glacial conditions. The curious reader will find, incidentally mentioned, ideas which afterwards were the means of earning credit to later writers. The radiation of ice from hill regions, and the re-arrangement of the drift on the lower grounds during emergence, he was content to note. But the excavation of hollows by ice he afterwards elaborated, and though opposition of all sorts has been active, his theory of the ice-wearing of lake basins solves a very large number of cases better than any other that has yet been brought forward. It is interesting to note that he did not at first appreciate the source of the difficulty felt by many of his critics, for his long familiarity with section-drawing made him forget that others were not so familiar and could not picture to themselves features on true scale. Huxley did him service by pointing this out. It was part of the Local Director's duty not merely to edit "memoirs," but also to superintend the execution of maps and sections. To this practice, following, as it did, on field-work, we owe the Plain of Marine Denudation first sketched by him in 1847, but later (1862) almost independently recognised and elaborated by Jukes in his classical paper on the river valleys of South Ireland which has so simplified our views on denudation. It was a very simple thing when explained, yet it represents a series of very fine generalisations and a strong grasp of geological processes. The solution of the difficult question, how rivers cut across mountain chains, was at once accepted as self-demonstrated, and its further application in later years to the valley of the Moselle received criticism mainly in details.

Those associated with Ramsay in the Survey work had often occasion to recognise the careless lavishness with which he threw out the generalisations dictated by years of observation and thought, generalisations worthy of detailed elaboration. A passing comment on a paper before the Geological Society sometimes summed up a long study, and by its announcement rendered further talk needless. The caution to students of glacial phenomena lest they should make too much of an episode

was wasted, for those under the domination of that *idée fixe*, that amiable monomania, had not realised the Glacial Epoch as of less importance than the Cambrian. I am aware that glacialists (they have selected that title for themselves) have small respect for the caution which is now amply justified; but it was Ramsay who recognised the value of Croll's hypothesis and introduced it to the notice of geologists (*Reader*, 1865). Early acquaintance with astronomical work doubtless made his interest in the hypothesis readier, but it is not of less merit that a man devoted to the practical study of a science was open-minded enough to accept as worthy of study an hypothesis which went beyond the facts of his environment and reduced to a minimum the influence of physical geography. Another generalisation has lain dormant far beyond the time within which it ought to have been re-discovered and promulgated as new. It was, for the time, a daring thing to speak of the Carboniferous limestone as an episode in the Later Paleozoic Period. It was uttered while the nomenclature of cataclysm was dominant, while Sir R. I. Murchison ruled, and, as ruler, adopted language implying the succession where now we recognise the overlapping of epochs. Murchison spoke of time-periods where we now recognise geographical areas. To Ramsay, the pioneer of the latter view, the Paleozoic Epoch was a succession of geographical pictures, and in one of these he saw the Carboniferous limestone sea, a Mediterranean in the Devono-Carboniferous land. I have attempted, in a notice in the *Philosophical Magazine*, 1888, to realise Ramsay's view by tabulating the land and marine areas so as to show what he meant by episodes.

The generalisation of the Red-coloured strata as indicative of lacustrine conditions was a remarkable one. No chemical investigation had then supported his contention, which rested merely on observation. The paucity of fossils, on which he largely rested his theory, would now be regarded as a slender basis, yet no subsequent enquiries have invalidated an opinion which was to some extent the product of intuitive perception of the relations of strata.

The publication of the "Physical Geology and Geography of Great Britain" marked an epoch in popular geology. Without pretensions to literary distinction, the plain narrative of a man

who was conversant with every detail, the book passed into a fifth re-written edition; its popularity was conquered by its directness. Ramsay had abundant critics, who declared that he did not respect the dignity of science. They are forgotten, because they mistook intumescence for dignity, rigid technicality for clearness. No one who heard Ramsay address the Royal Institution would fail to understand the secret of his success as a lecturer. Familiarity with the best English writers, perfect mastery of his subject, and thorough sympathy with the imperfect knowledge of his audience, gave him a grip which more pretentious speakers never acquired. He was a most methodical speaker, his lecture was planned out carefully by time, his subjects had each the number of minutes allotted, so that he never gave undue proportion to any section of his address. As a consequence he had never to change the plan of his lecture during delivery, for his auditors never tired of one topic before he had passed to the next; the whole was a continuous series of independent statements, reaching its climax when with the spark of his own intense conviction he welded them all into one harmonious unassailable conclusion. His personality counted for a good deal. A handsome presence, a native refinement which varied intercourse with all classes had converted into a courtly address, a fine sense of humour, and a curiously weak sense of his own power, all these enlisted his hearers in his behalf, and had he been far less accurate, far less earnest, would still have won their sympathy.

The work of Ramsay's life, the *magnum opus* on which his fame will rest, is the "Geology of Wales." It is a monument of solid work such as few men can look back upon. Only those who have attempted the study of Welsh stratigraphy can realise what that means. But the casual reader who has had no special interest in Wales will find in that classical memoir a vast amount of methodical research and careful inductive reasoning of infinite value in the investigation of other troubled regions.

But Ramsay's influence was perhaps even greater and more permanent as Director of the Survey. In this position he perhaps did not create (for De La Beche had begun the work) but he developed and maintained the English school of field geologists, which is characterised by accuracy of detail and systematic analysis of evidence. His inspection was very thorough, no point

escaped his notice. He had not the rapidity of Murchison in seizing the main features of a country, but he did not so often err. Above all, he possessed in a high degree the philosophic spirit which enabled him to look at every investigation, however local, as a contribution to the principles of his science. The masterly use he made of the unconformities in the Welsh series makes his paper on Breaks in Succession a chapter in the geography of Silurian times, while the discussion of the red rocks similarly opened a new vista in historical geology.

Personally he was a most lovable man, a true gentleman in the highest sense of the term. Of spotless integrity, loyal to his friends, considerate to those who differed from him, he was loved by his associates; even his quick temper never for a moment marred the sympathy between him and his officers.

The ten years of his retirement have allowed him to fall out of men's knowledge, but they have also permitted a calmer survey of his relation to science than would be possible had he more recently dropped out of the ranks.

Since the days of Playfair no geologist has approached the position of Hutton's great interpreter. I still regret that the suggestion I made to Ramsay, that he should edit the "Illustrations," was made too late, or rather that his health gave way so soon thereafter. His ripe experience, wide acquaintance with geologic phenomena and the relative literature, his open-mindedness and calm judgment would have entitled him to do for the science of the middle of the century what Playfair had done for that of his day. He has left no one behind him equal to the task.

No. XIX.—The Geology of Kyle. By James S. M'Lennan.

[Read 11th December, 1890.]

The District.—The middle portion of Ayrshire "that bears the name of Auld King Kyle" is separated from Carrick on the south by the River Doon, and from Cunningham on the north by the River Irvine. It contains the district drained by the Ayr and its tributaries—the Lugar, the Coyle, the Greenock, and the Fail, along with the northern slope of the Doon valley, the country sloping to the south, watered by the Irvine and its affluents—the Burn Anne and the Cessnock, and some 15 miles of the upper portion of the Nith basin. It is divided from the shires of Lanark and Dumfries on the east by a ridge of hilly ground, rising in some places to elevations of more than 1000 feet. Its greatest extent from east to west is nearly 25 miles, and from north to south 24½ miles. It has a low and sandy coast-line of nearly 13 miles, on which are situated the thriving sea-ports of Irvine, Troon, and Ayr.

In treating of the geology of this district it will be needful to arrange and describe the various formations in consecutive order, beginning with the lowest—the Silurian.

There is found in the south of Scotland, stretching right across the country from St. Abb's Head on the east to the North Channel on the west, a broad strip of elevated land, including the Lammermoor and Lowther Hills, known as the Southern Highlands, composed of rocks belonging to the Silurian system. Strata forming the lower portion of this formation are found in South Ayrshire, including the valley of the Stinchar, and part of that of the Girvan. In the latter they are remarkable for the abundance and variety of their fossil remains, first made known to the world by Sir Roderick Murchison.

Lower Silurians.—The only rocks in Kyle of Lower Silurian age—belonging to the Llandeilo series—occur in the vicinity of Loch Doon, and in the district lying further to the east, bounded by the Water of Deuch. Here on the north these rocks are surrounded by a large fault which brings alongside of them lower Old Red Sandstone strata, and near Dockloch those of Carboniferous age.

These Llandeilo rocks are made up of beds of hard grey and blue greywacke with, sometimes, thin layers of dark blue and grey

shales. In some places the greywacke becomes a conglomerate, enclosing rounded fragments of quartz, greywacke, and grit. Some 3 miles east of Dalmellington, a well-marked bed of this latter can be seen running along the side of Benbrack hill, containing pebbles as large as 4 feet in diameter. The officers of the Survey observed some faint worm-tracks in some of the shales in the vicinity of Loch Doon, the only evidences of organic life as yet discovered in the district. These Silurian rocks are also traversed by numerous veins or intrusive beds of pink felstone, which trend in a direction similar to the line of strike, viz., from south-west to north-east.

Upper Silurians.—In the valley of the Greenock Water rocks of Upper Silurian age (Ludlow and Wenlock) are met with. These form two long narrow areas stretching nearly parallel to each other—one to the north-west and the other to the south-east of the Ayr valley. They are a continuation of the rocks of the Lesmahagow district, and at Linn Burn and Lamon Burn, tributaries of the Greenock Water, contain many well-preserved fossil shells of several species. No crustaceans (*Pterygoti*) such as are found in all parts of the Logan Water district have been as yet discovered in the Muirkirk area.

Old Red Sandstone.—Between the Silurians and the lowest member of the Carboniferous system in Ayrshire there is found a great series of sandstones, flagstones, and conglomerates, with masses of interbedded rocks of igneous origin. These are regarded as belonging to the Old Red Sandstone, and have been divided by the Survey into lower and middle groups—the former running along the north-west side of the Silurian upland, while the latter lie unconformably on the first as well as on the Llandovery rocks of Upper Silurian age, and are covered in the same way by the lowest member of the Carboniferous series.

In the Dalmellington district the lower Old Red Sandstone consists of a narrow band of volcanic and aqueous rocks flanking the Silurian heights, and bounded on all sides by faults. The one running north-east and south-west divides it from the elevated region to the south, while those on the north and north-west bring it alongside of the Coal measures and Carboniferous limestone, and, south of the Doon, beside Silurian rocks of Caradoc age. The Old Red Sandstones consist of conglomerates, shales, and hardened

mudstones, with their intrusive felstones and mica traps. The conglomerates contain fragments of grit, felspathic sandstone, and quartz, all well rounded. The aqueous rocks are shales and sandstones, jointed and shattered, and sometimes much hardened in texture. The igneous rocks associated with, and of the same age as, these are made up of various porphyrites of either a dark purplish colour, dull, fine-grained, and amygdaloidal, or a lightish blue colour, less earthy and more crystalline in texture.

In the neighbourhood of Sorn this sandstone forms the well-marked hill of Blacksidend, rising to the height of 951 feet. Here, and also in the district of Lanfine moor, it is much flanked by faults which bring alongside of it rocks of Carboniferous age. Its strata consist of three different sets of rocks—(1) an upper set of volcanic beds, with conglomerates and ash-like sandstones; (2) a series of red and grey sandstones; (3) a lower group of rocks which have been very much altered. The quarries at Penning Hill, Changue Burn, belonging to the second set of this series, have yielded a characteristic fossil of the lower Old Red Sandstone—*Cephalaspis Lyelli*. The upper or volcanic series, so well developed in the Burn Anne near Galston, has long been famous for its pebbles. "These are usually turned up by the plough in the loose trappean soil, and have, doubtless, been derived from amygdaloidal and irregular cavities in the rotten and rapidly weathering trap rock."

The only place in Kyle where rocks placed by the Survey in the middle division of the Old Red Sandstone are found, is a little to the west of the village of Dalrymple, where they form a narrow strip on the northern slope of the Doon. This tract forms a part of the north-eastern margin of the district nearly comprising the angle formed by the Girvan and the Doon, and stretching along the coast from the Heads of Ayr to the mouth of the Girvan Water. Its rocks consist of reddish and greenish sandstones and conglomerates overlying the Silurians, a group of porphyrites of great thickness, a series of sandstones of various colours, beds of porphyrites, tuff, sandstones, and conglomerates, and, as their upper member, reddish micaceous sandstones, which, at the Heads of Ayr, contain specimens of the *Pterichthys major*.

The second group in upward succession, which consists of porphyrites, is locally developed to a great thickness, and forms

the heights between Maybole and Dailly, culminating a short distance north-west of the Doon in Carrick Brown Hill at an elevation of 940 feet. These form the best development of the middle Old Red Sandstone to be found in the county of Ayr.

Carboniferous Rocks.—The Carboniferous system covers a much larger area in Kyle than any or all of the other formations put together, and consists of the following groups in ascending order: —The Calciferous sandstone series, the Carboniferous limestone series, in some places the Millstone Grit, and the true Coal measures. The region it overlies may be divided into the following coalfields, which will be successively referred to—the Kilmarnock and Galston, the Ayr and Coylton, the Dalmellington, the Cumnock, Lugar and Sorn, the New Cumnock, and the Muirkirk coalfields.

In the Kilmarnock and Galston field, which extends from the river Irvine on the north to the Dundonald and Craigie Hills, to the Permian rocks near Mauchline on the west and south, and to the Old Red Sandstone of Auchmannoch on the east, the Calciferous sandstone is well developed, especially in the course of the Cessnock Water, from Auchmannoch Moor to Black Briggs, and from Craighead to Haining Mains. In this last locality the stream has cut a deep gorge, known as Craig Connor, bringing to view both members of the series. Good exposures of it can also be seen in Killoch Burn, Auchmillan Burn, and Burn Anne, as well as in the small streams flowing from the north-east side of the Craigie Hills. The series consists of a lower group of reddish coarse-grained sandstone with, here and there, bands of a concretionary coarse sandy limestone, known as cornstone. Remains of plants are met with in these sandstones, but are neither many in number nor well preserved. Over these occur a series of impure ferruginous limestones (cement-stones) and green, grey, and reddish shales, with beds of sandstone. The former contain *Entomostraca*, and the latter abound in some places with these and other organic remains, along with worm-tracks, ripple-marks, rain-pits, and sun-cracks.

The Carboniferous limestone series consists of a suite of sandstones, shales, and limestones, with seams of coals and ironstone.

Along the sides of the Craigie hills the cement-stone group of the Calciferous sandstone is overlaid by a bed of limestone, which, by numerous quarries, can be traced for a distance of more than 3 miles, from Inchgotrick farm to Cessnock Water at Dalla Hill.

This is supposed to be the lowest Howrat or Beith limestone of the Dalry basin, and at Howcommon consists of "black shale and ironstone, blue limestone about 4 feet, blue shales 3 feet, and a layer of white limestone 4 feet in thickness, resting on blue shales." The Survey gives a list of ten different fossil genera found in this bed. A mile west of Harelaw, in the same district, a second or upper band has been quarried, and it is thought to have its outcrop at Colliebarlees, a short distance to the east of Craigie village. In the course of the Burn Anne the lowest limestone is not so well developed as at Craigie, and the same diminished appearance obtains in its exposures at Killoch Burn, Wheitshaw Muir, and Auchmillan. In the second of these localities attempts have been made to work the thin coals associated with the limestones.

The Coal measures in the Kilmarnock and Galston district, like the other coalfields in Scotland, consist of an upper group of red and purple sandstones and clays without any coal seams, and the true Coal measures, made up of grey, white, and yellow sandstones, dark shales, fire-clays, coal seams, and ironstones. There are five workable seams in this locality —

M'Naught coal,	2	ft.	6	in.	to 3	ft.	6 in.
Tourhall coal,	2	,,	0	,,	6	,,	0 ,,
Major coal,	4	,,	0	,,	7	,,	0 ,,
Stone coal,	4	,,	0	,,	5	,,	8 ,,
Main coal,	7	,,	6	,,	11	,,	0 ,,

The Stone coal forms what is known as the "blind" coal of Caprington, which is thought to have become "blind" or anthracitic from the presence of an intrusive mass of igneous rock in its neighbourhood. The Main coal of Hurlford as it goes westwards gets split up into three separate seams, which are known as the Splint, Turf, and Wee seams; and though there are some 60 fathoms of strata between it and the limestone series these contain no seams that at present can be worked with profit, whereas in the Kilwinning field some good seams occur in these equivalents. A little distance south of the Permian rocks of Mauchline and Tarbolton a narrow strip of the Coal measures is met with, and at Rouchdike and Adamton coal has been worked. In the latter place it consists of two seams, one a gas coal, and the other a household coal $3\frac{1}{2}$ feet thick.

The district extending from the mouth of the Doon on the south,

and as far as Troon on the north, and inland to the foot of the Tarbolton hills by Stair and Drongan on to the south of the Craigs of Kyle (enclosing the coalfields of Ayr and Coylton), is bounded on its southern flank by rocks of the Calciferous sandstone group. The lower, or red sandstone series of this group is well seen along the course of the Doon from Cambusdoon to Auchindrane, and also above Dalrymple village. At Kerse Park, south of the Craigs of Kyle, these are found to contain remains of *Lepidodendron* and other coal plants. Its upper portion—the cement-stone group—can be seen well developed on the shore between Doon mouth and the Heads of Ayr, where some of its strata contain organic remains, such as cyprid cases, fish scales, and plants. Further inland there are few exposures of it to be met with owing to the depth of the drift, but some of its more calcareous beds, once burnt for lime—as evidenced by several old filled-up quarries and ruinous lime-kilns—testify to its presence.

The Carboniferous limestone series, which underlies the Coal measures, is not well represented. It can be observed a little to the south-west of the Craigs of Kyle at Bargenoch, but from that to the seashore no exposures of it are visible.

In this coal-field—the Ayr and Coylton—good natural sections of the various strata can be seen in the bed of the Coyle Water, as below the mansion-house of Sundrum the lower portions of the series are well exposed, and also between that and Garrochead the same stream flows over all the coals, and part of the overlying barren red sandstones. Sections of a like kind occur along the course of the Ayr, at Cameron's Holm and above Auchincruive.

The seams met with in this field are—

Ell coal, ...	3 ft. 4 in.
Craufordstone coal, ...	8 „ 0 „
Ayr Soft coal, ...	5 „ 0 „ to 7 ft.
„ Hard coal, ...	4 „ 0 „
Blackband ironstone, ..	1 „ 0 „

This ironstone is the same as the Burnfoot seam of Dalmellington, and has been found in bores to the south-west of Coylton village, but when worked there it was found to be unprofitable. The Ayr hard coal is the best in this district, and having been long wrought near that town is now exhausted. The upper barren sandstones, already referred to as well seen on the Coyle Water, are similarly

exposed on the Ayr between Sorn and Ballochmyle, and also on the Burnock near Ochiltree. They "consist of red, reddish gray sandstones; red, purple, or lilac clays and shales, with sometimes a thin band of fine white limestone," and these clayey beds sometimes contain remains of coal plants.

In the Dalmellington field the limestone series has been worked at Patna, and here also is found its only workable seam of coal. In some of the pits it measures 14 feet in thickness, while in others it gets split up by intervening strata into two and sometimes into four seams.

The chief seams are known as—

The Craigmark blackband ironstone,	10 in.
„ Sillyhole coal, ...	5 ft. 6 in.
„ Chalmerston coal, ...	4 „ 0 „
„ Minnivey coal, ...	3 „ 6 „
„ Burnfoot blackband ironstone,	2 „ 3 „

This last is the staple mineral of the district; at Waterside it has the above thickness, but thins out as it passes eastwards, till in the New Cumnock field it is only 2 inches thick. The Craigmark blackband, after being worked for some time, was found to turn into a gas coal as it passed eastward.

The Cumnock, Lugar, and Auchinleck field is merely an extension of the same strata as are found at Dalmellington. The limestone series is poorly developed, and its lower members occur at Laigh Holehouse and Blairmulloch, near Sorn. In the last-named place coal has been found, and at Laigh Broclar a gas coal has been worked. At Benston an upper seam of limestone has long been quarried.

The chief seams are—

Ell coal, ...	4 ft. 0 in.
Main coal, ...	4 „ 0 „
Claud coal, ...	2 „ 0 „
Maid coal, ...	4 „ 0 „
Low Maid coal, ...	2 „ 7 „
Blackband ironstone, ...	1 „ 7 „

In the New Cumnock field the concretionary limestones of the Calciferous sandstone have long been worked at Gelt and Craigdullart, chiefly for agricultural purposes. Good sections of the whole series can be seen along the Gelt and Glenmore Waters.

The limestone series is well developed, and consists of three groups—the lowest of which can be seen at Dalblair, and has been quarried at Dornal; and the upper one at Mansfield, Polquheys, and High Park. In the middle group are found the famous Edgehill coals, which form a little basin wherein the seams are very thick and close together, as is shown in the following section—

Gas coal, ...	1 ft. 8 in.
Strata, ...	10 ,,
Nine foot coal, ...	9 ,,
Strata, ...	16 ,,
Seven foot coal, ...	11 ,,
Strata, ...	12 ,,
Twelve foot coal, ...	12 ,,
Strata, ...	9 ,,
Three foot coal, ...	3 ,,

In 14 fathoms of strata there are 6 fathoms of coal, forming five seams. The strata between these seams are of varying thickness: a little to the east they disappear, and all the coals come together, forming a seam 40 feet thick. This lies in a little hollow known as "the ship."

The leading seams are known as—

Lane Mark gas coal, ...	5 ft. 4 in.
Boig or lower coal, ...	6 ,, 0 ,,
Eight foot coal, ...	8 ,, 0 ,,
Laird's coal, ...	3 ,, 2 ,,
Creoch coal, ...	4 ,, 1 ,,
Musselband, ...	3 ,, 1 ,,

Position of blackband ironstone.

This ironstone is here represented by an impure gas coal, or shale, used for making alum.

The Muirkirk coalfield is one of the richest and longest worked in Kyle. Here the limestone series is very well developed, having no less than ten seams of limestone. Of these, three have an average depth of 40 feet, and the other seven of nearly 3 feet, making a total thickness of 140 feet. They are highly fossiliferous, containing, according to the Survey, twenty-one genera and thirty-one species. This series also has nine seams of coal, four of which average 9 feet in thickness; six seams of clayband ironstone, with

an average thickness of 11 inches; and one seam of blackband 10½ inches thick.

Overlying these is the Millstone Grit, made up of white and yellow sandstones and grits, with seams of fireclay and thin coal. It is also seen in the Lugar Water at Wallaceton, but is much thinner than at Muirkirk.

Its chief seams are the following:—

Claud coal, ...	3 ft. 3 in.
Maid coal, ...	7 ,, 0 ,,
Low Maid coal, ...	3 ,, 0 ,,
Musselband, ...	0 ,, 6 ,,
Five foot coal, ...	5 ,, 6 ,,
Six foot coal, ...	6 ,, 6 ,,
Blackband ironstone, ...	1 ,, 0 ,,
Three other coals (average), ...	3 ,, 3 ,,

The blackband has been the chief object of search, and is the same as that worked at Lugar and Dalmellington.

"The clayband ironstones of this district were formerly largely sought for, and, when smelted by the cold blast process, made exceptionally good iron, which was then noted in the trade for its excellence; but since the discovery of blackband ironstones, and the invention of the hot blast, they have been allowed to remain unwrought. The ruins of the first blast furnaces erected in Scotland are still to be seen near Glenbuck, where these ores were formerly smelted."

Permian Rocks.—Lying in the middle of the coal-basin of Kyle is a large mass of igneous rocks and red sandstones of Permian age. These form an oval, having its greatest length from north-west to south-east, with its outside margin all round composed of porphyrites, melaphyres, and tuffs. Inside this, and overlying the above-mentioned rocks, is a set of brick-red sandstones, in colour and texture very unlike those of the Carboniferous formation. Good natural sections of these igneous rocks can be seen in the course of the Ayr near Ballochmyle and above Stair village. These are not the only evidences of volcanic action in Permian times met with in Kyle, for in many places the Coal measures are found pierced by masses of agglomerate, circular in form, which appear on the surface as small rounded hillocks. These "necks" were the vents through which volcanic material was ejected, and they

are frequent in the Dalmellington coalfield. Good examples also occur at Raithill, near Coylton; Sorn Hill, near Catrine; in Ochiltree village; Little Hill, near Craigie; and a group of five are found to the south-east of Symington.

The red sandstone group is easily known by its brick-red colour. The River Ayr has cut it

> "Through many a wild romantic grove,
> Near many a hermit-fancied cove,"

into a series of deep and picturesque ravines, where the nature and composition of the strata are well displayed. Similar good exposures occur on the Lugar; and at Mauchline it has been and is extensively quarried for building purposes.

Post-Carboniferous Igneous Rocks.—These in the twofold forms of irregular sheets or bosses and dykes or veins are found bestudding the coalfields. In the Kilmarnock field the two largest bosses form the hills of Craigie and Dundonald, and smaller ones occur at Symington, Troon Point, and Holmes near Galston. Further to the north, in the Ayr field, they are met with at Auchincruive, Enterkine, and the Craigs of Kyle. At Stair "a thick series of pale-grey shales has apparently been hardened by the heated masses so as to form the well-known whetstones or Water of Ayr stones." These igneous rocks form, in the Dalmellington district, the hills of Benwhat, Ewehill, Benbeoch, Benbain, &c., and they also cover a consider able area in the neighbourhood of Aird's Moss, near New Cumnock.

The other form these rocks of supposed Miocene age assume is that of dykes, which are wall-like masses varying in thickness from a foot or two to twenty or thirty yards. "They descend to an unknown depth, and do not all reach the surface, and preserve their course with singular persistence, irrespective of the changes of dip and strike, or the varying nature of the rocks." Some of their courses can be traced for a considerable distance, as that which crosses the river Ayr at Auchincruive, and from thence runs in a south-west direction across the Ayr coalfield for more than 2 miles. The direction which in general these dykes are found to pursue is from north-west to south-east.

Boulder-clay.—The drift series overlies the most of Kyle, and underneath it, or where it has been removed, the hard rocks are

found grooved and striated with the markings peculiar to the glacial period. In the south these striæ bear a north-west direction, turning more to the west as they leave the uplands and near the Clyde, while to the north their course is somewhat south-west, as is evidenced by the markings left on the hills stretching from Ardrossan to the confines of Renfrewshire. It would thus seem that central Ayrshire has been a meeting-place for the masses of ice that moved south from the Western Highlands, and north from the uplands of Galloway, Nithsdale, and Clydesdale. Blocks of metamorphic rocks are found in the Boulder-clay in the Irvine valley near Darvel, and in the valleys of the Lugar, the Glenmore, and the Gelt, and northwards to the slope of the Carrick Brown Hill range. Masses of grey granite from Kirkcudbrightshire are met with as far north as the heights of the lower Doon, and on the top of Genoch Hill, at an elevation of 1865 feet.

This deposit consists of two parts, an upper and a lower, the latter dark-grey or blue in colour over the Carboniferous areas, reddish over the Old Red Sandstones and porphyrites, and pale grey over the Silurians. It is hard and tough, and full of stones well rounded and striated, with here and there beds of sand, fine clay, and gravel. The upper is coarser, not so close in texture, and sometimes contains large blocks of stone more angular and less ice-worn than those found in the lower member. The group of sands and gravels overlying this clay is poorly developed in Kyle. About $1\frac{1}{2}$ miles north-west of the village of Ochiltree some well-marked ridges or "kames" are found, and similar ones occur between Old and New Cumnock, and in a hollow between Benbrack and Clafin Hills near Dalmellington, 1000 feet above sea-level. The fine clay, devoid of stones, generally lying in hollows, a wash-out by rains and rills from the slopes of the Boulder-clays, has yielded specimens of Arctic shells. These were obtained from a bed of this clay cut open by the Pow Burn, a little to the east of Monkton, and comprised *Astarte compressa* and *Natica clausa*.

Raised Beaches.—There are found along the coast-line of Kyle remains of three different terraces at varying elevations, which evidence the varying sea-levels. One of these occurs between Monkton and Crosbie old church, at some 60 feet over mean tide-

mark. A little to the east of Ayr racecourse there is the remnant of a second terrace, with the distinctly marked 40-feet beach constantly met with on the west coast of Scotland. The third terrace—the best defined and most continuous of the three—which has an average height of 25 feet and a varying breadth, stretches from the mouth of the Doon to that of the Irvine, and upon it all the coast towns of this district are situated. Its surface has been raised and roughened by the sand blown landwards from the existing sea-beach. Wherever vegetation has secured a hold the shapes of these mounds remain unchanged, otherwise their forms are modified by the action of every gale.

Alluvium.—In various parts of Kyle patches of alluvium are found. These are formed by the action of water laying down deposits of clay, sand, silt, loam, or gravel beside the courses of the streams. Sometimes these have been cut into several terraces by the stream flowing through the valley which they occupy, that of the present river being the lowest and most recent.

On the course of the Water of Ayr, from Stair to its mouth, good examples of these terraces are met with.

There are other patches, generally lying in hollows, which mark the sites of former lakes gradually silted up by the materials washed down into them, and by the decay of water plants, until at last they have become converted into meadows and cornfields. Some of the larger streams seem to have widened out into lake-like expansions, and these, partly by silting and by drainage (caused by the deepening of the river bed) have become fine alluvial land. Barleith Moss, a large hollow overlaid by alluvium, lying between the Irvine and the Cessnock, seems to have been formed in this way.

These ancient bogs or lakes are very frequent between Ayr and the Girvan valley, some now flat meadows or well-tilled fields, others marshes, or, where the inflow of sediment has been small, lakes with undiminished area. Several of these lochs in other parts of Kyle have been artificially drained, as that near Lochlee, which, at the time when Burns lived there (1777-84), covered some 20 acres, with double that extent in winter. A few years ago an interesting crannog or lake-dwelling was found within its area.

Peat.—The hills in the south and east of Kyle have their flat tops covered with a thin coating of peat, but this deposit, formed of accumulations of decayed vegetable matter, is deepest and most extensive on the lower grounds. Much of the surface once overspread by it has been reclaimed and brought under cultivation. Considerable areas are still covered by peat to the east of Dalmellington, and Aird's Moss, lying between the Ayr and the Lugar, contains an extent of 3 square miles, with a depth in some places of 20 feet. Further to the north lies another large moss called Burnfoot Moor. Some 3 miles to the east of Irvine, Shewalton Moss covers an area of more than a square mile.

No. XX.—Scenes and Sections in Thornton Quarries, East Kilbride, in 1868. By James Bennie, H.M. Geological Survey of Scotland.

[Read 7th May, 1891.]

The exhibition of a portion of the cranium of a reptile, by Mr. John Young, from Braehead Quarry, at the Society's meeting in November, 1890, and the report of it which I had from the Hon. Secretary, Mr. Murdoch, which stated that Mr. James Thomson also exhibited a duplicate of the same fossil from the same place, awakened recollections of many visits which I made to Braehead and Thornton Quarries in 1868, during which I gathered innumerable fossils of certain kinds, and examined and measured in detail the sections exposed in the most typical of these quarries. Some account of this work may interest the members, and may assist any one who should think of further exploration in search of reptilian remains or other fossils from the same group of strata in that locality.

The origin of my visits in 1868 was this. As Mr. Thomson had expressed a doubt whether the coral named *Fungites* by David Ure was really found in East Kilbride, I offered to guide him to some quarries in that parish where I thought *Fungites* might yet be found. My offer was accepted, and one suitable day we went to verify it in South Shiels Quarry, which lay in the southern part of East Kilbride.

Our way from Glasgow to South Shiels was by Carmunnock, Hairmyres, Newlands, and Crosshouse, partly by road and partly across country. After leaving Carmunnock the road passes through Braehead Quarries, and when we came to them, Mr. Thomson proposed a look in. I had some years before frequented them in search of fossils, and being interdicted therefrom, I had not visited them for some time; but now having a companion to champion me I thought I might break the taboo and dare the utmost rigour of trespass law. Accordingly Mr. Thomson leapt over the fence and I crept under it, and we passed along the shale heaps looking, like Autolycus, for any "unconsidered (geological) trifles" we could pick up. We had not gone very far when Mr. Thomson, who was in front, looted down, lifted something, gave it a look and shouted, "Man, I've got a big bone." After due inspection and admiration his prize was bagged, and our search continued. A little further on the same action was repeated and again came the shout, "Here's another bone," and truly another had been picked up lying loose, weathered out of the shale.

Thereafter we rambled over the other shale heaps and found several scales of *Rhizodus* and two or three small fish spines. We next entered upon the older workings on the east side of the road, finding a different shale in which coprolites were abundant, and soon we had our hands full of them. It is not necessary to recount further the day's proceedings, except simply to say that in Shiels Quarry Mr. Thomson found *Fungites*, and had his doubts as to whether Ure had really found it in East Kilbride completely dissipated. I may further say that henceforth the taboo was over for me, and that during the next three months I made frequent visits, twelve in all, to the Braehead and Thornton Quarries, ransacking every one, and every corner of each, and satisfying myself that little more was to be had.

The quarries were four in number, Braehead Old and New Quarries, and Thornton No 1 and No. 2 Quarries. Braehead Old Quarry consisted of a flat space formed by the tops of old shale heaps massed together, and a long sloping bank formed by the last couped shale. Over the flat space later outputs of shale had been tumbled down, and these often yielded good fossils, but the sloping face was necessarily the richest and most easily searched. Braehead New Quarry was then in active operation, with a large staff of

workmen, and a large kiln constantly burning. The shale heaps in it were fresh and the shale was often in large slabs, the time since they were quarried not having been long enough for the weather to break them up and crumble them down. It was therefore most prolific in large bones such as Mr. Thomson had got, and arge *Rhizodus* scales.

At Thornton the quarries were also an old and a new one. The old one had been long standing still, and the large kiln was in a ruinous condition. But working in it had been lately resumed, ere my renewed acquaintance with it in 1868, and a railway led from it to a series of open kilns outside, so that the quarry was free from kiln reek. Thornton New Quarry was situated 200 or 300 yards further south, and, having been opened only a short time, everything was raw about it; but it had this advantage, that it gave an opportunity of getting certain shells, whole or nearly so, which in other quarries were only to be had in fragments on the over-weathered shale heaps.

Of the fossils found in the various shales it is not necessary for me to give a general list, as that has been already done, and well done, by Mr. James Neilson, in his paper on "Some Sections of Carboniferous Limestone near Busby" (*Transactions*, vol. iv., p. 282), so I shall only indicate the species I found on the shale-heaps, and then describe in detail the section exposed in Thornton Old, or No. 1, Quarry, which was by far the most typical of the four quarries that I have mentioned.

And first, the class of fossils that began to arrest my attention was that of the coprolites, which were literally in thousands, generally lying loose on the weathered shale-heaps. They varied greatly in size, from 3 or 4 inches in length to less than 1 inch, and in thickness from an inch to that of a stout quill. In form they also differed much, some being fusiform, others cylindrical or conical, or even nearly globular. It was easy to see in most of them which end had been protruded first—it being blunt, while the other tapered to a point. In many a scroll-like disposition was visible, most clearly seen in those broken across. The surfaces of many were wrinkled while others were quite smooth. Generally the matter they were composed of was fine-grained and compact, but a few had scales of ganoid fishes imbedded in them, and one was coated with such scales.

Other fossils occurred, but not so frequently as the coprolites, still often enough to give a piquancy to the search, and to prevent it from becoming wearisome through monotony. The last of all were bones somewhat similar to those which Mr. Thomson hailed with a joyful shout, but not so big, and my eureka was whispered to myself; though sometimes when I found a large or extra good palatal tooth, for which I had then a passion, my exclamation was both loud and long. Occasionally conical teeth were got, which, from their appearance, I dreamed might be reptilian, as they differed from what I had been familiar with as fish, but of course I had to pass them with a point of interrogation attached to them in my mind. Encrinites were only represented in the upper shales above the main limestone by small ossicles in a thin band of green shale. Shells were chiefly confined, in the upper shale, to the bed above the limestone which Mr. Neilson has called the Hosie limestone. A few specimens of *Nucula* occurred in a perfect form, but small shells, which seemed to be *Spirifera Urei*, appeared in thousands. These were only in single valves and very friable, so they broke into dust as the shale weathered, and a passing glimpse was all I had of them. There was an entomostracan shale in which the shell-cases of these creatures were in thousands, but being in single valves they returned as dust to dust. Plant remains, in the form of roots, and more frequently rootlets, of *Stigmaria*, were seen permeating old soils now hardened into clay ironstone, and I have a record of finding a lepidodendroid cone and some twigs which showed signs of the internal structure being preserved.

In the course of gathering the fossils I soon found that certain forms characterised certain shales—that the coprolites, the fish scales and bones, the entomostracans, the marine shells and the encrinites, and finally the palatal teeth, occurred exclusively in shales that could be easily distinguished from one another. As the fossils differed essentially in character, some being marine, others lacustrine, while the plant roots and rootlets indicated unmistakably terrestrial conditions, it was manifest that, if a clue could be found, a succession of changes could be easily determined, and a history of the events that occurred in this corner of the Carboniferous world could be made out satisfactorily. Such a clue was instinctively sought in the section of strata exposed in the

face of each quarry according to the established geological law that lower and upper meant before and after. The intimate acquaintance I had made with the fossils and the different shales in which they were found enabled me to recognise readily the place of each in the section when at length I proceeded to examine and measure the different beds, in order to settle the chronological sequence they followed and the conditions they typified.

I shall quote the sections in Thornton Old, or No. 1, Quarry in detail, and in descending order, as the strata in it were more complete than in the others.

I measured it on August 16th, 1868—

		Feet.	Inches.
	Boulder-clay,	12	0
1.	Supposititious limestone,	1	0
2.	Black shale with oolitic nodules,	6	0
3.	Limestone (capstone of the quarrymen),	3	0
4.	Soft black shale, lower half fireclay,	0	11
5.	Ash-bed made up of:—		
	Ash, 6 to 8 inches,	3	10
	Bandstone, 19 ,,		
	Ashy shale with soft shale, 5 ,,		
	Bandstone, 14 ,,		
6.	Grey shale,	1	2
7.	Coprolite bed, with square nodules,	0	7
8.	Fish-scale shale (bituminous),	0	6
9.	Green shale, with fish spines and encrinites (marine),	0	2
10.	Ironstone,	0	4
11.	Fireclay,	0	3
12.	Ironstone,	0	4
13.	Entomostracan shale,	0	2
14.	Black shale and fire-clay,	0	7
15.	Limestone (impure),	0	7
16.	Shale with fish palates,	0	2
17.	Limestone,	1	2
18.	Shale (parting),	0	0
19.	Limestone,	0	9
20.	Shale (parting),	0	0
21.	Limestone,	2	8
22.	Shale (parting),	0	0
23.	Limestone,	4	8
24.	Hard shale,	0	7
25.	Soft black shale with fossils (marine),	2	6
26.	Ash-bed, with large pebbles, so far as visible	9	0

From the detailed description recorded in my note-book, I shall

now quote such remarks as may make the sections, and the conditions represented in them, more intelligible.

Boulder-clay. Light and loose in texture, but doubtless genuine, as in Thortonhall Quarry the limestone on which it directly lay was intensely glaciated.

1. Supposititious limestone, inferred from loose blocks lying upon the next bed.

2. Black shale, crowded with fossils. In Thornton Old Quarry it was 6 feet in thickness, but in Thornton New Quarry it was nearly double that. It contained many nodules of ironstone, which on the outside appeared as if of oolitic structure, but in the inside were as compact and hard as iron.

3. Limestone (capstone), with no fossils. This limestone and the shale above are the Hosie limestone of Mr. Neilson.

4. Soft black shale, lower half fireclay. This bed is important as representing a land surface. From it descend into the next bed innumerable rootlets of plants, apparently Stigmarian, which exist as black stripes among the grey ash.

5. Ash-bed. That this bed represents a period of volcanic activity there can be little doubt, as the greater part of it is composed of volcanic débris. Mixed with the ash is much shaly matter, showing that the ash fell into water into which ordinary sediment was carried by water currents while the ash was wind-borne, and both were deposited by gravitation. In the midst of this ash-bed occur large concretions of very hard compact stone, which are locally known as "bandstone." They are permeated by rootlets; perhaps they were originally nests of irony mud which collected in hollows of the ash-bed.

6. Grey shale. Had also the appearance of being mixed with ash, but more as dust than pebbles. There is nothing organic in it.

7. Coprolite bed with large square nodules. This was the most interesting bed in the section. The coprolites were numerous and good, as already stated. The nodules were also numerous, and in parts the bed was almost made up of them.

8. Fish-scale bed, bituminous. It was spoken of by the quarrymen as a coal, meaning thereby that it burned in the fire, and Mr. Thomson called it an oil shale. It was full of fish scales, small rhomboidal scales, which seemed to be in millions. There

were also large scales, Mr. Thomson getting one 1½ inches in diameter, and Mr. Armstrong one double that. It had much vegetable matter associated with it, showing, I think satisfactorily, that it was of fresh-water origin. It was very fissile and tough.

9. Green shale. Very tough, and in all the other quarries except Thornton Old Quarry, it broke up into grains. It is in this shale that the fish spines, which are common here, occur. As on the surface of the slabs some truly marine fossils were found, such as small ossicles of encrinites, *Spirifera bisulcata*, and spines of *Producti*. We must suppose these tell of an invasion of the sea in a region of land surfaces and fresh-water lakes.

10. Ironstone, 4 in.
11. Fireclay, 3 in.
12. Ironstone, 4 in.

These are grouped together as in Braehead New Quarry, and in No. 2 Quarry, Thornton; the ironstone is not divided, and is 7 inches in thickness.

13. Entomostracan shale. This consists of black mud with cases and casts of *Leperditia Okeni* in single valves, which are sometimes felted like seed-cases in oil-cake. In Thornton No. 1 Quarry this shale lay immediately under the lower ironstone, and was only 2 inches in thickness. In Braehead Old Quarry it lay in a bed 28 inches in thickness, of a soft black shale-like fireclay, and was 7 inches in thickness. In Thornton No. 2 Quarry the entomostracan shale was absent, and the bed it should have been in was 14 inches in thickness.

14. Black shale and fireclay, 7 inches, contained petrified plants, stems, and fruit-like bodies, one a cone of *Lepidodendron*, and in Thornton No. 2 Quarry Stigmarian roots 4 or 5 inches in diameter, composed of ironstone.

15. Limestone, impure, 7 inches. This is the first marine bed that occurs below the fresh-water series. The chief fossils were small ossicles of encrinites.

16. Shale, with palates in extraordinary numbers. I have recorded *Psammodus porosus* and *Cochliodus magnus* perfect, with many others, sometimes twelve or a score being got at a gathering.

17 to 24. The divisions of the main post of limestone. Being hard and compact, few fossils were got from them, but I have a record of *Productus giganteus* 4 or 5 inches in length.

25. Soft black shale. Marine fossils of well-marked Carboniferous types were abundant in it.

26. Ash-bed, with large well-rounded pebbles in parts like a conglomerate. In Thornton Old Quarry 9 feet of it are visible. In the railway cutting south of the quarries 20 feet are visible, and in Kittoch Glen 50 feet of it are seen in the cliffs.

The foregoing is a summary of what I saw and found in these quarries in 1868, and I recount the story in order that the members of the Society might know of it, and, knowing it, might direct further researches to those parts where things not got before might be met with.

The parts which represent the land and fresh-water conditions are those which, I think, might be most profitably examined and studied, in preference to those laid down under marine conditions, which have already been thoroughly worked out by Mr. Neilson in his paper previously referred to.

But with the middle portions of the sections—the shale, the bandstones, and the ironstones lying between the two limestones, more might yet be done, as witness the recent finding of the cranium of a reptile by Mr. James Anderson, lately exhibited by Mr. John Young. For this purpose the sections might be examined more thoroughly than I did, as being essentially a searcher of shale heaps I did not quarry, but simply took what the quarrymen and the weather gave freely to my hands.

In the old quarries of Brachead and Thornton the output of shale was extensive, and much of it was buried up again ere it was thoroughly weathered. Explorations might yet be made into these old shale-heaps and the shale-blocks taken out and examined for the peculiar fossils yet remaining in them.

Another suggestion is that the layer of shale, No. 16 in the section, might be sought for and quarried for the sake of the palatal teeth which might be found in it, as they seemed numerous enough to repay any such trouble. I have a record that, from a small quantity of it which I stumbled upon incidentally, I got about a dozen small palatal teeth, and after two or three weeks further weathering I got as many more. From this fact those who care for such fossils may know where to seek for them *in situ*.

The next bed to which I may direct attention is the great bed of ashy conglomerate, which underlies the main limestone. It

can be seen on the left side of the cartway to the mouth of the old disused kiln at Thornton. It was visible all the time I was searching the quarry heaps, and I often took a look at it as a contrast to the fine shale above that limestone. It seemed to belong to a different world—a world in which nothing was to be seen or heard but "water breaking on stone,"—as the water-worn grit and pebbles were the only things in it that indicated the circumstances of the times in which they were deposited. In Thornton Old Quarry about 9 feet of this bed were visible, and in the railway cutting south of Thornton a hummock of it, about 20 feet in thickness, was cut through. In the latter exposure all the peculiarities which distinguish it are better seen, and its character as a great deposit of volcanic débris, washed, moulded, and assorted by water, is manifest at a glance. In the Kittoch glen, near the mill, cliffs of it about 50 feet in height were seen by me in 1872.

In the Geological Survey maps of the district (Lanark, Nos. 16 and 10, 6-inch scale), this conglomerate is shown as a band 150 yards in breadth, extending along the south side of East Kilbride parish for a distance of $5\frac{1}{2}$ miles, from the eastern edge of sheet 16 to the fault at the junction of the Kittoch Water with the White Cart. But in the neighbourhood of Thornton, Braehead, and Phillipshill it has a breadth of about half-a-mile, and a superficial area of about 2 square miles. As the surveyor who mapped the district, Dr. James Geikie studied its character and origin much better than anyone giving only casual glances at it. His description, as contained in paragraph 40 of the "Explanation" to sheet 23, 1-inch map, may be fitly quoted—"The igneous rocks (those of the Eaglesham hills) are, where no faulting intervenes, invariably fringed with a set of conglomerates, tufaceous or ashy grits, sandstones, shales, &c., which may be considered either as the top beds of the volcanic series, or, perhaps with greater propriety, the basement beds of the Carboniferous limestone series. . . . Their general character is that of dull meagre yellow and yellowish green tufaceous grits, shales, and sandstones, with beds of red and mottled laminated tufaceous clays, and in some places courses of conglomerate, the stones of which have been derived from the adjacent trappean masses. In some portions the beds

are calcareous and contain abundant fossiliferous remains. They are exposed at Benthall Rig and West Drumloch, where also the overlying main limestone is opened in quarries. An excellent section also is laid bare in Kittoch Water, which has cut through the conglomerates, and exposed the underlying igneous rocks. They are likewise well seen in a brook at Laigh Walkerdyke, and again at Strathaven, while an excellent section is laid bare in the stream at West Rylandside near Drumclog. There the deposits consist of a considerable thickness of brown and red mottled ashy fireclays and mudstones, which are here and there charged with small rounded stones. With these beds are associated thin limestones and calcareous shale (full of Carboniferous limestone fossils), grey and white sandstones, dark shale, thin coal and fireclay.

"The origin of these deposits is sufficiently evident; they have undoubtedly been derived from the tear and wear of the underlying igneous rocks, and indicate the old shore-line of the Carboniferous limestone sea. It would thus appear that, after the igneous forces which had given rise to the trappean rocks of the district became nearly or altogether quiescent, a long bank of land stretched westward from Strathaven, and was washed by the sea along its borders. The deposits laid down at this time form the passage between the Calciferous sandstone series and the overlying Carboniferous limestone, but they appear upon the whole to be more closely connected with the latter than the former."

In confirmation of the statement that in some portions "abundant fossiliferous remains" occur, I may refer to page 58 of the same "Explanation," where a list of ten species of common Carboniferous fossils is given, from "shale bands in ash below main limestone," at Shieldburn near Benthall. I may also mention that Mr. Neilson, in the paper already quoted, gives a list of about forty species of the most characteristic Carboniferous fossils found by him in the black shale, which in Thornton Quarry lies immediately upon the ash conglomerate. From both these instances we may gather that this conglomerate truly represents the "shore-line of a Carboniferous limestone sea."

No. XXI.—The Leaf-Caves of Mull. By John Dougall, M.D., Professor of Materia Medica, St. Mungo's College, Glasgow.

[Read 12th November, 1891.]

These leaf-beds, or leaf-caves as they are locally called, were first made known by the Duke of Argyll in 1851.* They are situated on the south shore of Loch Screden, which lies on the west side of Mull, having near its entrance, and almost opposite, the famed island of Staffa. This part of the boundary of the loch forms a low basaltic promontory called Ardtun, which has on its other side a wide land-locked bay, at the head of which stands the village of Bunessan.

The leaf-caves are about 2 miles from the village, and are of easy access; but to see them to advantage the tide must be on the ebb. I believe that there are three caves to be found within a short distance of one another, but as it so happened during my visit that the tide was flowing, I only saw one of them, though that was fortunately the one where the fossil leaves are chiefly to be found. It can now scarcely be called a cave; it is more properly a huge fissure, or small gorge, which slopes through the sea-cliff to the tide-level, and to which access is therefore comparatively easy. That it once, however, has been a cave, in the strict sense of the word, is easily seen by an examination of its structure, and by observing its situation. The huge breakers which expend their strength upon this rocky wall during a north-west gale are quite sufficient, if time enough is conceded, to produce the effects observed. In this case the strata have first been tunnelled by the waves into a cave, and this being enlarged gradually by the same process, the roof fell in, and the small gorge which presently exists was thus formed.

In descending this gorge from the cliff above, the first thing which attracts attention is a bed of conglomerate about 4 feet thick. It lies nearly horizontal, and consists almost exclusively of jaspers and the usual varieties of flint pebbles, some as large as an orange, and all very firmly cemented together. In Jukes' "Geology," 1854, this rock is said to consist of "burnt red and yellow chalk flints." In some portions I also observed small

* I am informed by Dr. M'Kechnie, of Bunessan, Mull, that they were really discovered by Murdoch M'Quarrie, who afterwards went to Melbourne.

angular bits of chalk limestone similar to that found on the coast of Antrim.

Further down the gorge is a large accumulation of blocks and slabs of what appears to be indurated shale; most of these are, I believe, the result of a series of blasting operations made a few years ago by Mr. Starkie Gardner, F.G.S., at the instance of the Duke of Argyll. This stratum of shale contains the leaf-bearing beds, and the object sought to be attained by the blasting was a more thorough examination of them than any which had hitherto been made. Amongst these shale blocks I found some fragmentary portions of leaves and what I took to be part of a fern, probably the *Filicites Hebridicus*, as figured by Jukes. As I had neither hammer nor chisel with me on the occasion of my visit, I had to be content with picking up specimens that some former visitors had either overlooked or had intentionally left.

On getting down to the sea-level a scene is presented to the eye which I think no one who has ever seen it, be he geologist or not, can ever forget, and the massive grandeur and wonderful form of which no oral or written description, however minute or graphic, can convey more than a faint idea. I have seen the Giant's Causeway, Fingal's Cave and the Clamshell Cave in Staffa; all of these are doubtless on a larger and more imposing scale than the aggregation of columnar basalt to be seen at Ardtun, but, so far as my memory serves me, their columns do not assume anything like the same variety of positions—horizontal, vertical, angled or arched—nor are they so distinct in their outlines.

In any case, there is to be found here as varied and striking an exhibition of columnar basalt, and one which affords as magnificent examples of basaltic crystallization, as can anywhere be met with.

Standing apart from the sea-cliff, and a short way into the sea, is a large coniform mass of rock, the base of which consists of basaltic columns and the upper portion of volcanic ash. It bears some resemblance to the sea-stack in the north-west of Orkney, well known as the Old Man of Hoy.

According to the Duke of Argyll the whole of the Outer Hebrides is composed of Laurentian gneiss, and it "is the basement upon which are piled the mountain ranges of the north-west of Scotland." He goes on to say, "The Mull mountains are composed almost entirely of volcanic rocks; yet not a vestige remains

of the volcanic vents from which those great masses of melted matter have been poured forth. Some of the trap mountains of Mull lie on beds of the old crystalline Silurian rocks; others of them are piled on strata of the Oolite and Lias, while others cover the débris of chalk, and may range through many of the Tertiary ages."

The basaltic promontory of Ardtun already mentioned has revealed in its leaf-beds that "once there existed on this area some great country covered with the magnificent vegetation of the warm climates of the Eocene* age." These remains are thus believed to bridge over in some degree the great gap between the Cretaceous and the Post-cretaceous or Tertiary ages. "Nothing of that country or of its vegetation now remains except a few autumnal leaves impressed upon the clays of some ancient river, or shallow lake or marsh, and sealed up under sheets of lava." The whole of it has "foundered amidst fanatic storms," or has been disintegrated chiefly by the ocean, which Hugh Miller speaks of as "that blue foaming dragon whose vocation it is to eat up the land." Even of the new surfaces which were formed out of the volcanic outbursts there remain only a few fragments broken up into capes and headlands and "caverned islets in the sea."

The succession of the beds as seen in the gorge which I visited is, according to the Duke of Argyll, as follows, in descending order:—

Uppermost basalt, ...	40	feet.
First leaf-bed, ...	2	„
First ash-bed, ...	20	„
Second leaf-bed, ...	$2\frac{1}{2}$	„
Second ash-bed, ...	7	„
Third leaf-bed, ...	$1\frac{1}{2}$	„
Amorphous basalt, ...	48	„
Columnar basalt† to low tide level, ...	10	„
	131	feet.

The bed of conglomerate which has already been alluded to is associated in one place with the first ash-bed. A thin seam of

* Jukes, *op. cit.*, says "Miocene."

† The basaltic columns are now at least 30 feet in length.

coal is also found in one place underlying a sheet of basalt, and has been thought to be the accumulation of the vegetation forming one of the leaf-beds.

By some observers the ash-beds are described as resembling the tuffs of Mount Dor, Vesuvius, and Madeira; the leaf-beds as composed of baked clay or very fine mud. This may be judged of to some extent from the specimens which I now exhibit.

A collection of the leaves obtained at Ardtun was exhibited by the late Professor Edward Forbes, who said of them, "The general assemblage of leaves is decidedly Tertiary, and most probably of that stage of Tertiary termed Miocene. Their climatal aspect is more mid-European than that of our Eocene flora. There is a striking resemblance between some of them and fossils from Styria and Croatia."

These plant remains have been referred to various genera and species, comprising plane, yew, alder, and rose (leaves), equisetum (stems), chestnuts, conifers, and palms, a plant common in Japan named *Salisburia*, a fern, *Filicites Hebridicus*, and several other vegetable forms.

No. XXII.—Peculiar U-shaped Tubes in Sandstone near Crawfurdland Castle and in Gowkha Quarry, near Kilwinning. By John Smith, *V.P.* With an Illustration. [Plate No. X.]

[Read 12th February, 1891.]

Two years ago when examining the sections exposed in the Crawfurdland Burn, near Crawfurdland Castle, 2 miles north-east of Kilmarnock, I observed on certain parts of the sandstone rock a number of peculiar U-shaped markings, with which I was not at all familiar. A portion of the sandstone containing one of these markings, which I detached from the rock, was placed in the Hunterian Museum, Glasgow, and Mr. Young informed me he had never seen any similar markings before, suggesting that I should send a note on them to the Society. Lately, when in the Crawfurdland district with Mr. Carrick, I made a more minute

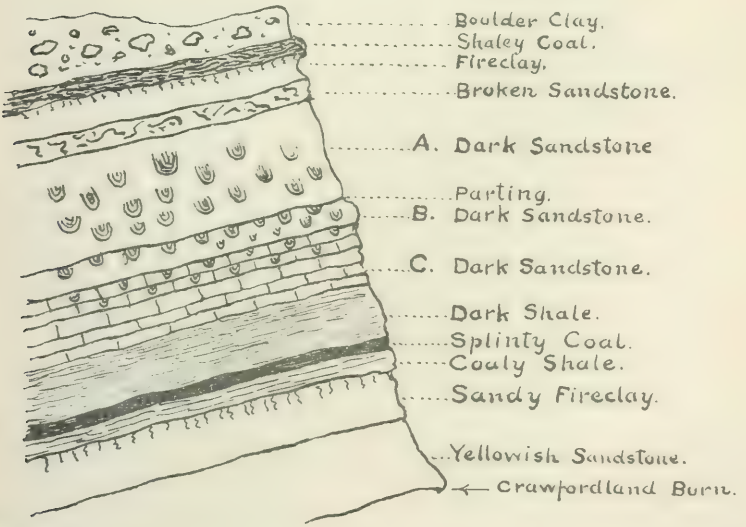
examination of the beds, and found the section exposed on the west side of the Crawfurdland Burn to be as follows :—

		Feet.	Inches.
	Shaly coal,	0	10
	Fireclay,	0	10
	Broken sandstone,	0	5
A.	Dark sandstone, with a few U-shaped markings and some plant rootlets,	3	4
	Shale parting,	0	1
B.	Very dark sandstone, with many U-shaped markings,	0	10
C.	Dark sandstone plies, with a few U-shaped markings on upper ten inches,	2	3
	Dark shale,	1	4
	Splinty coal,	0	4
	Coaly shale,	0	8
	Sandy fireclay,	2	0
	Yellowish sandstone, forming bed of stream.		

The beds dip to the south as shown on section [Plate No. X.], and the U-shaped markings are first seen here and there in the top part of bed C. The animals which formed the markings had commenced to dig into what was probably for the time being the bed of an estuary, and continued to live in that position till further sedimentation buried up their homes, when they or their descendants again began to dig and form fresh habitations in the overlying bed. In the section at Crawfurdland this process has been repeated many times. Bed B is literally crowded with them, and on breaking off some of the more shattered parts of the rock-face, the markings are seen to have the uprights of the U always at right angles to the plane of rock-bedding, and the plane of the U's lies to all the "airts" of the compass.

The only other fossil U-shaped tubes with which I am acquainted are those from the Cambrian sandstones named *Arenicolites didymus*, and the U-shaped tubes formed by the living amphipod crustacean, *Corophium longicorne*, which are abundant in the muddy sand in the lower part of the estuary of the Garnock Water below Kilwinning. In both of these instances the habitation of the animal has been formerly and is now a simple U-shaped tube. But the

COROPHIOIDES POLYUPSILON, Smith, sp. nov., full size



J. SMITH, DELIN.

SECTION SHOWING POSITION OF U-SHAPED TUBES.

CARTER & PRATT, LITH.

U-shaped tube markings on the sandstone of Crawfurdland and Gowkha are very different.

Beginning as a simple U-shaped tube of about $1\frac{1}{2}$ inches wide by the same in height, the animal appears to have enlarged its tube or habitation to accommodate its increasing circumstances till it reached as much as 4 inches wide and 5 inches high, these being the largest measurements I have taken. Between these extremes they are to be met with of all sizes. In these cases the animals appear to have been cut off by sedimentation or by other causes. They resemble a lot of distorted and crushed up U's of different sizes, placed one within the other. To enable the animal to form this structure it has apparently broken through the outer and under sides of its tube and has reformed its habitation, in some cases as many as eight times. It is therefore only the last dwelling-place or the largest outer U that is preserved in an entire state, though this is not always the case. This shows that at this stage the tube was circular in section, and from $\frac{1}{4}$ to $\frac{3}{8}$ths of an inch in diameter.

It is, of course, impossible to tell what kind of animal formed these peculiar tubes; the only living one which forms a U-shaped tube with which I am acquainted is the little amphipod crustacean already mentioned. The sandstone rock in which the tubes occur is of course one of the worst kind of matrices for preserving organic remains, especially the delicate parts of amphipods. If the tubes were formed by annelids, which I do not think is very likely, it might yet be possible to discover their horny jaws. But even this is doubtful.

The U-shaped *Arenicolites didymus* found in the Cambrian strata of the Longmynd, where, like the tubes of the Garnock *Corophium*, they occur in thousands, are thought to have been the habitations of annelids (Nicholson's "Life History of the Earth"), but I think it is more likely that the tubes now under notice were constructed by crustaceans. Gosse remarks of *Corophium longicorne* that it comes out of its burrow and beats about on the mud with its long antennæ, but although I have many times visited the estuary of the Garnock, where these little crustaceans have their homes, I have never seen them do this. On taking up their U-shaped tubes, which, from the upper part of the tube to the bend, are between 1 and 2 inches long and very

slender, with just enough of mucus plastered on the inside to keep them together, it is found that by breaking them and looking through the upper part a small hole, which would do little more than admit a pin, has been left, and it is very likely that the little crustacean keeps up a circulation of water through its habitation by drawing it in at one end of the tube and forcing it out at the other. This is probably to supply it with oxygen for breathing and with "small fry" for food, although it has got the reputation of catching and devouring animals much larger than itself. To see these small openings in the ends of the tube the operation must be very carefully performed, and the surrounding wet sand must be left about it, as the tubes are so fragile that they will not, when bared, sustain their own weight.

The U-shaped markings at the Gowkha Quarry, north-east of Kilwinning, are scarcely so large as the Crawfurdland specimens, but evidently belong to the same species, and appear to occur at the same geological horizon, as the Highfield or Clonbeith limestone, one of the upper beds of the Carboniferous limestone series, is found at a short distance above the beds in which they are contained. As I previously remarked, I think it is very likely that these peculiar structures have been formed by a crustacean, and have therefore named the fossil *Corophioides polyupsilon*, Smith, *sp. nov.*

The *Arenicola piscatorium* or lob-worm, much used by the fishermen for bait, lives in the sand in estuaries, and on the sea-shore between tide-marks. It inhabits a hole which opens on the surface at both ends. One end is called by the fishermen "the eye," and from the other are thrown up those peculiar sandcasts so abundant on many of our shores. The tube of this animal is rather bow-shaped than U-shaped.

No. XXIII.—The Sand-hills of Torrs Warren, Wigtonshire. "*Wo der Sand der Dünen Weht.*" By John Smith, *V.P.*

[Read 10th December, 1891].

From Glenluce to Sandhead, in Wigtonshire, a distance of about 6 miles, there stretches a line of sand-hills of varying breadth, narrow at both ends, but widening out to about one mile and a-half towards the middle. Torrs Warren occupies a central position in this district, and within the last ten years has been rendered famous by the number of archæological relics that from time to time have been discovered in it.

As to the name "tor," it is evidently the Celtic for a hill or knoll. We have Torbolton, the hill of the baal fire; Tormore, the big hill; and the Torbane, vulgarly called "The Rumple."

The other day I visited this famous locality with a friend, and spent a few very interesting hours wandering over its ever-varying surface. There is perhaps no other place in the West of Scotland where a few such quiet hours can be spent, for one may wander about to his heart's content without seeing a single individual, or even a "footprint on the sands of time," with the exception of those he is impressing at every step, and which the next breath of wind will effectually blot out of existence, or perhaps cover up with the drifting sand and preserve for ages.

The very first thing that catches the archæological eye on entering Torrs Warren is the immense quantity of flint chips interspersed amongst the gravel which may be seen wherever a sufficient quantity of sand has been blown by the wind from any particular spot. In fact, before the use of phosphorus matches became so common, this locality was the great magazine to which the people of the surrounding neighbourhood used to resort when they required to lay in a supply of flint to use with the "fleerish" or steel, and tinder or touchwood, or, at a later date, with match-paper, to obtain a light.

But the old prehistoric men had no steel wherewith to strike fire with flint; though they had discovered another substance, which they called pyrite or firestone, and with it and a bit of flint they were able to produce fire. Bits of this pyrite are frequently found in old graves, or in the earthen urns got in them. In fact our word "fire" is just a form of the first part of pyrite, viz., "pyr."

We have also this word "pyr" in pirates, or the fire-raisers, who very likely carried on their depredations on land before they took to the seas, and in funeral "pyre;" and we shall see by and by that in the tors the funeral pyre must often have been lighted. In fact the word funeral has not yet passed out of common speech, for instead of people saying they are going to a burial, they quite as often say that they are going to a funeral, as if the body was going to be burned.

Torrs Warren presents us with many pictures of a type that have not yet found their way on to canvas; for variety they completely take precedence of our much smaller Ayrshire sand-hills nearer home. As in all moving sands, we have the recently-drifted part with its long smooth slopes and exquisitely curved outlines, in places covering the bent half knee-deep or, it may be, drowning it completely. One knows in a moment when he has got on to a newly-drifted part by at once sinking over the shoe. The part from which the sand has been drifted presents quite a different aspect. It is weather-beaten, and behind each bit of straw, stone, or other hard material there is a trail of sand, generally covered with fine dust, while here and there a small stone is seen perched upon the summit of a short pillar of sand. If the hill is bent-covered at such a place, the slope is as steep or even steeper than that of a railway bank.

In Torrs Warren there are generally three layers of soil found at different levels. The bottom layer may be seen cropping out on the side of a sand-slope, and perhaps placed 20 or 30 feet above the gravel and flint-debris-covered bottom of a hollow between two hills. The second layer is generally a few feet above the first one, and the third is just below the growing vegetation covering the hills. From their dark colour these layers of soil are very conspicuous, interbedded, as they are, with the light grey sand. Of course they have derived their colour from the growth and decay of the varied vegetation which has covered many parts of the Torrs. Where the drift of sand has been slow, a layer may be 6 or 8 feet deep, but it is generally much thinner, often not a foot in thickness. A very marked feature in connection with these soil-layers is that the flint chips and implements occur only on the top of the *bottom layer;* and in no instance did we see them above any of the others, though, of course, where the bottom

layer has been blown away the flints have found their way down to the Raised Beach gravel. On the top of the lowest soil-layer it was also noticeable that very few stones were to be seen, and such as there were had in all likelihood been brought there by human agency. In fact the bottom soil-layer seems to lie on top of the old Raised Beach (possibly beaches), and it is only from the sand underneath it that the beach pebbles have been derived.

Nearly every flint one finds amongst the Torrs occurs as a chip, and these chips are innumerable. Sometimes we pick up a core from which flint flakes have been struck. The chips and cores are just the remnants left over after the more suitable pieces have been taken off for implements or weapons. The old Ayrshire flint-worker would have been glad of many of these chips, for flint seems to have been much more common in Wigtonshire than in Ayrshire. On the sands of the Torrs are to be seen, here and there, unbroken pebbles of flint. That all the flints have originally come from the stratified beach beds I think there can be no doubt. Small flint nodules have been picked out of the beach beds near Dunragit, which is just what we find in Ayrshire, but the proportional quantity of flint there is much less than at the Torrs, the reason appearing to be that the latter locality was much nearer the source of supply than Ayrshire.

I once ventured the opinion, when treating of the Ayrshire flints,* and have since seen no reason to change it, that the flints of the West of Scotland have been brought from the North of Ireland, the transporting agency having been sea-weed. It has been suggested that such flints may have been brought from Ireland by ice, but we have no evidence that ice was present in our seas during the Raised Beach periods. There are *no glacial shells* in the Raised Beach beds. In fact their fauna indicates a temperature as mild as that of the present day; and it appears to have been during this period that the gigantic oaks, the remains of which are found under our peat mosses, flourished all over the land.

It has also been suggested that the flints are of native origin, derived from a Chalk formation which once covered part of the south-west of Scotland. But the great difficulty with this theory is that no flint has ever been found in the Boulder-clay. It is, however, possible that we once had a Chalk formation, the remains

* *Transactions*, vol. vi., p. 185.

of which were completely swept away during the first advances of the great glacial sheet.

The Torrs' flints are generally of a light greyish colour. Some of them are yellowish, or even reddish, like the bulk of the Aberdeenshire flints, and a few are dark coloured, occasional bits being almost as clear as glass, but with a slight milkiness. During my visit I picked up a few small pieces of the real Irish white chalk-limestone, and I have seen similar specimens amongst the Ayrshire sand-hills.

It was interesting to note the variety of vegetation which grows on these barren sand-hills; certainly not barren as regards certain kinds of plants, which are in sufficient abundance to support a quantity of rabbits, and, what we did not expect to see, a considerable number of grouse. There is, first, the inevitable bent or marram, *Psamma arenaria*, which seems to thrive best when it is much covered up, in fact almost drowned, by the drifted sand. Here and there, but not so abundant as the bent, we find the sea-sedge, *Carex arenaria*. The stem of this plant keeps under the sand, and runs along for several yards in a nearly straight line, sending up at pretty regular intervals a few green blades and an occasional flower-stem. The little silky willow, *Salix fusca*, commands attention from the peculiarity of its growth. Sometimes we see it covering considerable areas as with a carpet. At other times we find it in detached clumps of a circular or ovoid shape, which rise into small dome-like masses. Sometimes these clumps assume considerable proportions, 12 to 20 feet in length, standing clear up from the sandy floor to the height of 6 or 7 feet; some of the more elongated ones, as seen from a short distance, resembling immense hedgehogs.

The field thistle, *Cnicus arvensis*, is found in considerable patches, and it seems always to prefer the hollows amongst the Torrs, where it looks like a plantation of young fir trees. In fact, so striking is this resemblance that a close inspection had to be made before we were satisfied that we were mistaken, its growth being somewhat modified by the rabbits having nibbled at it. Two species of heaths, *Erica cinerea* and *E. tetralix*, the fine- and the cross-leaved heaths, are abundant on certain parts, the former predominating. *E. tetralix* had ceased to flower, but the fine-leaved heath still held forth a gorgeous show of crimson flowers.

Both these plants seem to be little, if at all, touched by the rabbits. It was quite different with the heather, *Calluna vulgaris*, which was cropped to the very ground, and in many places looked as if it had been literally shaved with a razor. This plant seems to be a tit-bit with several animals. Sheep and grouse feed largely on it. "Ye grouse that crap the heather bud." In some parts of the Torrs the heather has assumed a very peculiar and striking form. This appears to have resulted from the combined action of its own growth, the dew, the sand, and the rabbits. At these places the heather is found in dense sub-globular clumps, which stand prominently up from the sand, or from other surrounding herbage. These clumps vary from a few inches to several feet in diameter, and give to this part of the landscape quite a foreign appearance which, if put on canvas, would scarcely pass in an art gallery as having been taken from any scenery that this country possesses. The genesis of these "heather dumplings," if I may be allowed the expression, appears to be this. The dew having wetted the heather, the drifting sand adheres to it. After a few days of calm weather the plant sprouts a little without the young shoots getting dusted with sand. These young sprouts are immediately nibbled off by the rabbits, so that, like an oft-clipped hedge, the heather, finding it cannot grow freely outward, forms a dense mass. Repetition of this process during a number of years—the dew, the coating of sand, and the constant and careful attention of the rabbits—has produced these peculiar dense clumps.

Certain parts of the Torrs are covered with a dense carpet of mosses of lovely shades of green, and at other places we see patches of sheep fescue grass cropped as close as a well-kept bowling-green. Ragweed, Isle of Man cabbage, bladderwort, and the lovely pansies all so common on our sand-hills, were conspicuous by their absence. But as the Torrs Warren is extensive, and it would take several days to visit every nook and cranny in it, it may have been that during our short visit we had not reached the "region" of their growth.

From the Torrs Warren within the last ten years an immense quantity of prehistoric antiquities have been collected. Thousands of flint implements and weapons, including arrow-heads, saws, scrapers, borers, hammers, flakers, &c., have been got. A number

of stone celts, some of them made of a material not found in this country, indicating a commercial intercourse with, if not actually an invasion by, some foreign people, have been found, also hammer-axes of various patterns, perforated to receive a wooden shaft. Stone melting-pots have been laid bare by the drifting of the sand, and fragments of ancient pottery, with an occasional complete urn, have been found. Our "finds" during our short visit, though not great, were not to be despised. We obtained a few worked flints, a "chapping-stone" hammer, as the natives term the conventional hammer-stone, a stone polisher, and some fragments of ancient pottery. We also got a coin about the size of a sixpence, made of a very brittle white metal, which was unfortunately broken under the impression that it was a thin bit of stone. On close inspection some of the ornamentation can still be seen, and I have no doubt that in the hands of an efficient numismatist it could be made out.

We also came across the remains of two ancient ironworks, and the slag-hill of the larger one contained about 10 cwt. of heavy black slag, scarcely to be distinguished, unless from its unique appearance, from the "bulldog" of the modern furnace. These ancient furnacemen perhaps did not know the use of lime, or if they did they may have discarded it. Their process of manufacture was probably similar to that still practised in the interior of Africa, as follows:—Two skins worked alternately give the necessary blast, a rapid action producing malleable iron, and a slow one giving steel, the iron having time to absorb a sufficient quantity of carbon. Wood reduced to charcoal would perhaps give the necessary fuel, and in corroboration of this I found a bit of the slag with several cavities where pieces of wood charcoal had once been imbedded in it, the fibrous appearance of the wood still showing on the slag. We subsequently learned from the rabbit-catcher that when this old furnace-hearth was at first blown bare, numerous pieces of burnt clay of a material resembling the ancient pottery was dug up on the spot by him. The slag is quite similar to the pieces which turn up now and then on the Ayrshire sand-hills, and to that which I obtained from the top of the Ardrossan shell-mound.

On some parts of the Torrs, covering small areas, nearly every stone to be seen is angular, presenting the look of having at

one time been heated red-hot. Unless such had been the case, it is difficult to account for their appearance. I think it is not unlikely that these stones mark the localities where the prehistoric people had their huts, and that the stones having been repeatedly used as heaters, by being made red-hot and plunged into the water to be heated, had split in the process. They appear not to have had any kind of dish that could withstand fire-heat without breaking in the process. No remains of ancient dwellings have ever been found amongst the Torrs, but small pavements formed of water-worn stones have sometimes been blown bare, and most probably had formed the floors of huts. Occasionally the very spots where the old flint-tool manufacturers worked have been exposed, the implements and materials which they used lying as they had left them, such as an old piece of pottery holding the flints, a stone anvil and a hammer, both considerably battered by usage, numerous flint-flakes which had not been considered good enough to convert into tools or arrow heads, and all bearing strong evidence that the old flint-worker had carried on his manufactures in the locality.

On a flat part of the Torrs we came across a circular ring of stones, which would be about 6 feet broad, and the circle ten paces in diameter. The stones were all water-worn, and 3 to 5 inches in size, a large proportion being of white quartz. In the centre of the ring was a number of calcined bones. From these appearances we came to the conclusion that this had been a burial ground, and we subsequently learned from the rabbit-catcher that when first blown bare of sand he had obtained from the inside of the ring two urns filled with calcined bones. The bones had been broken into pieces about the size of a finger, so that they might be more easily packed and take up less space in the urns than if they had been left entire, or as the fire had left them. Over the urns had in all likelihood been raised a small mound of sand, and the water-worn stones appear, from the position in which they now lie, to have been placed round the bottom of the mound and partly up the sides, but not carried right over the top. They had probably been used both as a protection against the wind and as an ornament to the mound—its top being probably turfed over; and certainly this simple and primitive grave, which very likely held the remains of some of the chiefs of the people.

would look quite as well as many a more imposing structure. It is difficult to understand what could have first led these primitive people to adopt such a terrifying process as the burning of their dead relatives. Was it done from sanitary considerations, or to prevent the bodies from being devoured by wild beasts?

The urns found within this ring are now in the Museum of the Society of Antiquaries of Scotland, as well as many hundreds of the flint implements, &c., found amongst the Torrs. In one place, along with the calcined bones, was got a bronze dagger, a polisher, and four white quartz pebbles. Some speculation has been ventured as to the significance of white pebbles as accompaniments of burials. The use of white pebbles as a happy symbol seems to be very ancient, and the Romans had their *calculi candore laudatus dies*, as memorials of happy days well spent. It has been suggested that white pebbles were placed only in the graves or urns of those who had lived an exemplary life, and if so the ancient of the old Torrs who got four white pebbles placed in his urn must have been a very worthy individual. It is not unlikely that this ancient custom suggested to the writer of the Book of Revelations—"To him that overcometh will I give to eat of the hidden manna, and will give him a white stone, and in the stone a new name written, which no man knoweth saving he that receiveth it." The "black balls" at ballots of the present day are just a continuance of the ancient practice; when a condemned criminal received his sentence there was handed to him a black pebble.

As to the genesis of the Torrs, they have, like the Ayrshire sand-hills, had two origins, the greater part of the sand having been derived from the 21-feet beach and the rest from the present sea-shore. To every person who possesses a camera, or a paint-box and a brush, and knows how to use them, we would say, visit the Torrs Warren. The first train from Glasgow lands you at Dunragit Station at 9.20, and within half-an-hour's walk of the spot. No art-gallery of Scottish scenery can possibly be complete that does not possess a few views of the Torrs.

No. XXIV.—Notes on the Group of Carboniferous Ostracoda found in the Strata of Western Scotland, with a Revised List of Genera and Species.

By John Young, F.G.S., *V.P.*

[Read 12th February, 1891.]

The work of discovery and after determination of the several genera and species of the fossil bivalved division of the Crustacea, termed Ostracoda, which are found in the Carboniferous strata of Western Scotland, has engaged the attention of several of the members of this Society for at least thirty years. Now that the group, so far as discovered, has been very fully determined, described, and figured, thanks to the long-continued labours of two of our distinguished honorary members, Prof. T. Rupert Jones, F.R.S., and Mr. James W. Kirkby, who have made its study one of their chief specialities, we are in a position to draw up for record in the pages of the Society's *Transactions* a more extended and correct list of these organisms than any yet given. Messrs. Jones and Kirkby have also been assisted in many of their determinations by Dr. G. S. Brady, F.R.S., a gentleman who has done a vast amount of good work in the investigation of the recent Ostracoda; his name therefore appears in the lists as one of the authorities for the names of several of the Carboniferous species.

The earliest record of shells from Scottish Carboniferous strata since determined as belonging to the Ostracoda, is that of the Rev. David Ure, in his "History of Rutherglen and East Kilbride," 1793, where, in plate XIV., he figures four species of "microscopic shells that can only with difficulty be perceived by the unassisted naked eye." Their true nature was unknown in Ure's time, but his mounted specimens, which still exist, are found by Professor Jones to belong to at least four genera of Ostracoda. For nearly sixty years after Ure's time nothing seems to have been done in searching our Western Carboniferous strata for further examples of this group.

It may be of interest to mention that up till 1865, some seven years after the formation of this Society, not more than five or six species of Ostracoda, including those found by Ure, had been recorded from the Carboniferous strata of Scotland. In that year Messrs. Jones and Kirkby issued the first of their series of papers on the Carboniferous Ostracoda; in one of

their recent papers, that for 1886, they record no less than 107 species, belonging to 21 genera, found in the Carboniferous strata of Western Scotland, and they further state that Western Scottish strata "have yielded a great number of Ostracoda, more species, in fact, than any other portion of the Carboniferous system, either in Scotland, England, or elsewhere" (*Quart. Jour. Geol. Soc.*, London, 1886, p. 502).

If our Society takes any credit for the greater amount of work done by its members than seems to have been the case elsewhere, in searching the various local Carboniferous strata for this special group of minute organisms, the credit is, I think, greatly due to the encouragement continuously received from Messrs. Jones and Kirkby, through the series above referred to, with their several determinations and figures and descriptions of the newer forms. This series of papers, of which there are now fourteen, has appeared in the *Annals and Magazine of Nat. Hist.*, *Geological Magazine*, *Quarterly Journal* of the Geological Society, *Proceedings* of the Geologists' Association, and *Transactions* of the Manchester Geological Society, and forms the basis of a monograph on the whole group of which two parts have already been printed, for the Palæontographical Society, in 1874 and 1884.

When our members first began their searches for localities which yielded Carboniferous Ostracoda, the particular stratum from which Ure obtained his specimens was not known; all that he stated regarding their localities being "Laurieston and Stuartfield, East Kilbride," without any mention of the nature of the bed in which they were found, or their mode of occurrence.

In a letter to Professor Jones, dated 4th July, 1865, and printed in one of the papers referred to (in the *Annals*, 1866), I was glad to be able to announce the re-discovery of the stratum yielding the *Kirkbya Urei*, Jones, and the other species figured by Ure. This stratum is the now well-known bed of fossiliferous shale lying between the two posts of limestone, which extend over a considerable area of Blantyre and East Kilbride. This shale, after further investigation, has yielded several other species of Ostracoda, as well as many other forms of Microzoa, it being one of the richest for organisms yet found in the West of Scotland. The quarries where Ure found his specimens are no longer accessible, but there are others of more recent date scattered all over the district, and

these will be found noted in the "Catalogue of Western Scottish Fossils," 1876, under the "List of Localities for Carboniferous Fossils."

The Ostracoda found in the Carboniferous strata of Western Scotland are obtained from certain fossiliferous beds, in each of its chief divisions, viz., the Calciferous sandstone series, the lower limestone series, the lower coals and ironstones, the upper limestone series, and the upper coals and ironstones. The division, however, which has yielded the greatest number of genera and species is that of the lower limestone and its accompanying shales, chiefly of marine origin. In the strata, believed to be of lacustrine or fresh-water origin from their fossil evidence, and from the absence of characteristic marine remains, as in the case of those strata which compose the lower and upper divisions of our coal and ironstone series, there are found certain forms of a small group of Ostracoda highly characteristic of these so-termed lacustrine conditions, and some of the species of which are found to range in time from the lower to the higher beds. The Ostracoda, wherever they appear, have evidently been very abundant in the waters in which these strata were being deposited, as their minute shells are often seen to have largely contributed to the formation of the beds. As a general rule they are hardly ever found mingling with the characteristic marine forms, which shows that the conditions under which the two groups lived were different.

Should any member of the Society who is forming a collection of Carboniferous fossils desire to add the Ostracoda he will find the methods of collecting and mounting them fully given in a paper which I read to the Edinburgh Geological Society in 1880 and printed in their *Transactions* (vol. iii., p. 290).

Very few fossiliferous localities which are found to contain either lacustrine or marine beds have not yielded some of the forms noted in the list appended to the present paper, but, of course, such forms are not found everywhere equally distributed. One that may be abundant or moderately common in one locality, may be rare or altogether absent in another, while some species, so far as yet known, are confined to one particular stratum in one locality. In spite of all the work which has up to this time been done amongst our strata, I believe there are still other forms to be discovered either in beds which have already been well searched, or in new localities and horizons of strata.

In one of the papers by Messrs. Jones and Kirkby already referred to, there are two tables, No. 1 showing the stratigraphical distribution of the Carboniferous Ostracoda in Scotland and the North of England, and No. 2 giving the genera and species and their occurrence, so far as found, in the Carboniferous strata of England, Scotland, and Ireland. The second table is of great interest as it shows not only the occurrence but the apparent disappearance of many of the species, as the group is traced over the Carboniferous areas of Great Britain and Ireland. As previously stated, Western Scotland is credited with 107 species, Eastern Scotland with 70 species. Of this number 6 are not included in the list from the West, but the total for Scotland, East and West, is 116 species. England, North and South, has a total of 110 species, of which 4 are given as of doubtful occurrence. Ireland has yielded only 46 species, 2 of which are doubtful. The total for Great Britain and Ireland is therefore 182 species, including varieties, allocated amongst 34 genera and sub-genera. Of the 110 species recorded from England, 41 have not yet been found in Scotland, and of the 46 species found in Ireland 21 are absent from Scotland. On the other hand, when the list from Scotland is compared with the English and Irish ones we find that of Scottish species 51 are absent from England and 92 from Ireland, while of the 46 species from Ireland only 16 are present in English and Scottish strata.

I have no doubt that further research amongst the Carboniferous strata of Great Britain will discover many of the Ostracoda at present unrecorded from the several areas noted, but the general evidence, as presently known, so far as Table II. shows, is that many of the species were limited by physical conditions existing at the time they lived to certain areas of the sea and old lake bottoms, and probably by the varying temperature of the waters and other conditions under which this group of organisms existed.

I shall now shortly summarise the genera of Carboniferous Ostracoda found in Western Scotland, commencing with the larger forms in the order of Table II. of Messrs. Jones' and Kirkby's paper. Most of these larger forms have been found chiefly in the beds of the purer marine limestones, such as those formerly worked in the Bathgate quarries, at Braidwood, Carluke, and at Trearne,

Beith, one horizon in the quarry at the Beith locality having yielded the greatest number and variety yet obtained. The same mode of occurrence seems also to hold good with those found in England and Ireland, the greater number of the larger forms being chiefly derived from the limestones.

Cypridina.—This genus is represented in the Carboniferous strata of Great Britain and Ireland by 13 species, 10 from Western Scotland, and all, with the exception of 2, from the limestone, these 2 being *C. primæva*, M'Coy, and *C. radiata*, Jones, Kirkby, and Brady. From one large fish coprolite from the limestone strata of Braidwood Gill, Carluke, which was sent me by the late Dr. Rankin, Carluke, in 1865, I extracted over 300 specimens of the shell of *C. primæva* with the valves united. This is a rare form elsewhere. *C. radiata* is found in shale in connection with the Airdrie blackband ironstone of our Upper Coal measures, and is also rare. I am inclined to add one other form of *Cypridina* not previously recorded in our list. This is a moderately large, oblong, oval species, one example of which I have found in the Trearne limestone, and which I provisionally place with the *C. oblonga*, J., K., and B., as found in the Irish limestone.

Cypridinella is represented by 7 species, of which 3 are found in the limestone of Beith and Bathgate. One of these, *C. Cummingii*, J., K., and B., is not recorded in the list of Messrs. Jones and Kirkby, but I have found a few examples in the Trearne limestone.

Cypridellina.—This genus is represented by 10 species, including varieties, of which only one species, *C. intermedia*, J., K., and B., has been noted from Scotland, but there in both the Eastern and Western districts. Of the other 9 species 7 have been found in Ireland and 2 in England.

Cypridella is represented by 6 species, 5 of which are found in our Western strata, 4 from the lower and 1 from the upper limestone. This genus has not yet been recorded from any of the English localities, but 5 of the species are found in Ireland.

Cyprella.—Of this genus 3 species are recorded, all from Scotland, only 1 of them being from our Western beds. They are all found in England, and 2 of them in Ireland.

Bradycinetus.—This rare form is represented by only 1 species, *B. Rankinianus*, J. and K., one or two examples of which were dis-

covered by the late Dr. Rankin in small ironstone nodules from the limestone of the Gare beds, Carluke, the only place where it has yet been discovered. Dr. Rankin's type specimen is in the Hunterian Museum.

Entomoconchus is represented in Great Britain and Ireland by 3 species, 2 of which are found in the Trearne limestone of the Beith district. This genus is the largest form amongst Carboniferous Ostracoda yet obtained from British strata. Some of the examples from the Irish limestone exceed in size those found in Scotland.

Polycope.—This genus is represented by 3 species, 2 found in Western Scottish beds. These have been obtained from shales and small ironstone nodules found on the horizon of the Hosie limestone in the lower limestone series at Campsie, Carluke, and Busby.

Entomis is represented by 4 species, only one of which, *E. biconcentrica*, found by Dr. J. R. S. Hunter, in the Braidwood limestone, Carluke, is known in Scotland. The same species is the only one of the genus yet found in Ireland. The other 3 species were found in the North of England limestones.

Cytherella.—Of this genus, 19 species, including varieties, are recorded; but 3 of these are doubtfully referred to the genus. From Western Scotland 15 species are noted, being found in marine strata, which extend from the Calciferous sandstone series up to the strata of the upper limestones. Several of the species, however, are restricted to certain horizons and localities.

Leperditia.—In this genus 16 species are recorded from Britain and Ireland, 9 being found in the West of Scotland. The genus is chiefly marine in its mode of occurrence, but there are at least 2 species, *L. Scotoburdigalensis*, Hibbert, and *L. Youngiana*, J. and K., which seem to have inhabited brackish or lacustrine waters, in which characteristic marine organisms are absent.

Beyrichia, as now determined, holds a greater number of the species of Carboniferous Ostracoda than any of the other genera here noted, 20 species being recorded, of which no less than 15 are found in Western Scotland. With the exception of 2 species, the genus is essentially marine in its mode of occurrence, being found associated with all the fossiliferous limestones and shales. The 2 species excepted are *B. arcuata*, Bean, and *B. subarcuata*, Jones,

the former being found in the lacustrine or fresh-water strata of the Upper Coal measures, and the latter in similar strata of the Calciferous sandstone series, and the middle coals and ironstones of the limestone series.

Beyrichiopsis.—Of this new genus 3 species are recorded, of which 2 are noted from the Calciferous sandstone series, in both Eastern and Western Scotland.

Kirkbya was first established by Professor Jones for a form found in the Permian strata of England. It is now found to be represented by 13 Carboniferous species, of which 10 are from Western Scotland. These are found both in the marine limestones and shales of the lower and upper limestone series, but certain of the species are confined to special localities and horizons.

Carbonia is represented by 10 species, 7 found in Western Scottish strata. This genus was established for the reception of certain forms belonging to a group highly characteristic of the lacustrine or fresh-water strata which alternate with the coal-beds both in Scotland and England, but which is seldom or never found associated with those Ostracoda essentially marine in their occurrence. It is not recorded from Irish Carboniferous strata, but will probably yet be found amongst its coal-beds.

Bythocypris is represented by 3 species, all noted from Eastern and Western Scotland, and found in the limestone and shales.

Argillœcia.—This is a genus at present represented by only 1 species, found in Eastern and Western Scotland and also in England. It is noted as of doubtful occurrence from Ireland.

Macrocypris is represented by 2 species, 1 rare and found as yet only at Millburn, Campsie. The other is noted from Eastern and Western Scotland—England and Ireland as doubtful.

Bairdia.—This genus is represented by 17 species, including 1 variety, and one form in which the genus is marked as doubtful. They are essentially marine in their mode of occurrence, and several of the species are plentiful, but some of the others are very rare. Of the 17 species recorded from Britain, 14 are found in Western Scotland, and only 1 is noted from Ireland.

Bythocythere is a genus which is represented by only two species, 1 found in Western Scottish strata, in the limestone shales at Brockley, Douglas coalfield, where it is rare. The other species is from England.

Cythere(*?*) is represented by 10 species, but the genus is marked as of doubtful occurrence in the Carboniferous strata of Britain, and the species recorded in the list of Messrs. Jones and Kirkby are there placed only provisionally with *Cythere* (*?*) until further investigation is made. With regard to the species, they seem all to be good persistent forms. Of the 10 noted 3 are recorded from Western Scottish beds, but I am inclined to identify a form found in the Calciferous sandstone strata, from the coast near Heads of Ayr, with that of *C.* (*?*) *superba*, J. and K., this species being found in similar strata in Eastern Scotland.

Youngia.—This is the last genus on the list, and at present only 1 species is known. It was discovered by me in the limestone shales at Robroyston, north-east of Glasgow, in 1872, the only locality where it has yet been obtained. The form is very minute, but it is moderately common in the shale. Its chief characteristic, in which it differs from that of the other Ostracoda here noted, is "its toothed hingement, which is certainly unique among the Carboniferous Entomostraca, though partially represented in *Cytheridea* among later forms." This hingement is something like that seen in shells of the genus *Arca*.

In conclusion, I am inclined to think that as further investigations go on amongst the Carboniferous Ostracoda a better knowledge will be gained regarding several of the genera, in which some of the species are now placed, so that the present list must be so far looked upon as only provisional. This desirable end can be much helped in many cases by the discovery of better-preserved specimens of some of the forms than those yet obtained, as it is only the external forms and surface-markings of the fossil Ostracoda that those palæontologists who have taken up the group for investigation have had to work upon. In many cases it may yet be found that where palæozoic forms have provisionally been placed with recent genera, the discovery of any new characters in finer specimens of the older forms may lead to a change in the present arrangement and to the creation of new genera for their reception.

Having always taken a deep interest in the collection of the Microzoa or smaller organisms found in the Carboniferous strata of the Western Scottish coalfields, I cannot let this opportunity pass without mentioning the names of the other members of this

Society, who, along with myself, have had the privilege of assisting Messrs. Jones and Kirkby with specimens for investigation, and upon which their list of Western Scottish Carboniferous Ostracoda has been built up. These are—Messrs. James Armstrong, James Bennie, Robert Craig, Dr. J. R. S. Hunter, David Robertson, John Smith, James Thomson, the late Dr. D. Rankin, and the late Dr. William Grossart. Nearly all of these names are mentioned again and again in Messrs. Jones and Kirkby's papers, and are honoured as discoverers by having certain new species named after them.

List of Papers and Monographs by Messrs. Jones, Kirkby, and Brady, on the Carboniferous Ostracoda of the British Isles, which contain references to Genera and Species found in Scotland.

1. "Notes on the Palæozoic Bivalved Entomostraca—Münster's Species from the Carboniferous Limestone."—*Ann. and Mag. Nat. Hist.*, May, 1865.

2. "Notes on the Palæozoic Bivalved Entomostraca—Some Carboniferous Species."—*Ann. and Mag. Nat. Hist.*, July, 1866.

3. "On some Bivalved Entomostraca, chiefly Cypridinidæ of the Carboniferous Formations."—*Quart. Jour. Geol. Soc.*, Lond., Aug., 1873.

4. "Notes on the Palæozoic Bivalved Entomostraca—some Carboniferous Ostracoda from Russia."—*Ann. and Mag. Nat. Hist.*, 1875.

5. "Notes on the Palæozoic Bivalved Entomostraca—Some Carboniferous Species belonging to the genus *Carbonia*, Jones."—*Ann. and Mag. Nat. Hist.*, July, 1879.

6. "Description of the Ostracodous genus *Bairdia*, M'Coy—From the Carboniferous strata of Great Britain."—*Quart. Jour. Geol. Soc.*, Lond., Nov., 1879.

7. "Notes on the Palæozoic Bivalved Entomostraca—On some Carboniferous Species of the Ostracodous genus *Kirkbya*, Jones."—*Ann. and Mag. Nat. Hist.*, March, 1885.

8. "Notes on the Carboniferous Ostracoda of the North-west of England."—*Geol. Mag.*, Lond., Dec., 1885.

9. "On some Fringed and other Ostracoda from the Carboniferous Series."—*Geol. Mag.*, Lond., Oct., 1886.

10. "Notes on the Palæozoic Bivalved Entomostraca—On some undescribed species of British Carboniferous Ostracoda."—*Ann. and Mag. Nat. Hist.*, Oct., 1886.

11. "Notes on the Distribution of the Ostracoda of the Carboniferous Formations of the British Isles."—*Quart. Jour. Geol. Soc.*, Lond., Nov., 1886.

12. "A list of the Genera and Species of Bivalved Entomostraca found in the Carboniferous Formations of Great Britain and Ireland."—*Proceedings of the Geologists' Association*, Lond., vol. ix., 1886.

13. "On Carboniferous Ostracoda from the Gaytan Boring, Northamptonshire."—*Geol. Mag.*, Lond., 1886.

14. "On the Ostracoda found in the Shales of the Upper Coal measures at Slade Lane near Manchester."—*Transactions Manchester Geol. Soc.*, 1890.

15. "A Monograph of the British Fossil Bivalved Entomostraca from the Carboniferous Formations—Part I. The Cypridinidæ and their Allies."—*Palæontographical Soc.*, Lond., 1874.

16. "Monograph, Part I., No. 2. The Cypridinidæ and their Allies."—*Palæontographical Soc.*, Lond., 1884.

LIST OF THE GENERA AND SPECIES OF OSTRACODA RECORDED IN THE PAPERS AND MONOGRAPHS OF MESSRS. JONES, KIRKBY, AND BRADY, AS FOUND IN THE SEVERAL DIVISIONS OF THE CARBONIFEROUS STRATA OF WESTERN SCOTLAND.	Calciferous Sandstone Series.	Lower Limestone Series.	Lower Coal and Ironstone Series.	Upper Limestone Series.	Upper Coal and Ironstone Series.
1. *Cypridina primæva*, M'Coy.		x		x	
2. ,, *radiata*, Jones, Kirkby and Brady					x
3. ,, *brevimentum*, J., K. and B.		x			
4. ,, *Youngiana*, J., K. and B.				x	
5. ,, *Hunteriana*, J., K. and B.		x			
6. ,, *oblonga*, J., K. and B.		x			
7. ,, *Grossartiana*, J. and K.				x	
8. ,, *Phillipsiana*, Jones.		x		x	
9. ,, *Thomsoniana*, J. and K.				x	
10. ,, *scoriacea*, J. and K.				x	
11. *Cypridinella Cummingii*, J., K. and B.		x			
12. ,, *superciliosa*, J., K. and B.		x			
13. ,, *vomer*, J., K. and B.		x			
14. *Cypridellina intermedia*, J., K. and B.		x			
15. *Cypridella Edwardsiana*, De Kon.				x	
,, var. *septentrionalis*, J., K. and B.		x			
16. ,, *Koninckii*, Jones.		x			
17. ,, *obsoleta*, J., K. and B.		x			
18. ,, *Wrightii*, J., K. and B.		x			
19. *Cyprella chrysalidea*, De Kon. var. *subannulata*, J., K. and B.		x			
20. *Bradycinetus Rankinianus*, J. and K.		x			
21. *Entomoconchus Scouleri*, M'Coy.		x			
22. ,, *globosus*, J., K. and B.		x			
23. *Polycope simplex*, J. and K.		x			
24. ,, *Youngiana*, J. and K.		x			
25. *Entomis biconcentrica*, Jones.		x			
26. *Cytherella inflata*, J. and K.		x			
27. ,, *simplex*, J. and K.		x			
28. ,, *valida*, J., K. and B.	x	x			
29. ,, *Benniei*, J., K. and B.	x			x	
30. ,, *recta*, J., K. and B.		x		x	
31. ,, *concinna*, J., K. and B.		x			
32. ,, *brevis*, J., K. and B.		x		x	
33. ,, *obliqua*, J., K. and B.				x	
34. ,, *æqualis*, J., K. and B.				x	

LIST OF THE GENERA AND SPECIES OF OSTRACODA RECORDED IN THE PAPERS AND MONOGRAPHS OF MESSRS. JONES, KIRKBY, AND BRADY, AS FOUND IN THE SEVERAL DIVISIONS OF THE CARBONIFEROUS STRATA OF WESTERN SCOTLAND.	Calciferous Sandstone Series.	Lower Limestone Series.	Lower Coal and Ironstone Series.	Upper Limestone Series.	Upper Coal and Ironstone Series.
35. *Cytherella obesa*, J., K. and B.		x			
36. ,, *scrobiculata*, J., K. and B.		x		x	
37. ,, (?) *rotundata*, J., K. and B.		x			
38. ,, (?) *reticulosa*, J. and K.		x		x	
39. ,, *extuberata*, J. and K.	x				
40. ,, *attenuata*, J. and K.	x				
41. *Leperditia Okeni*, Münster.	x	x		x	
42. ,, *suborbiculata*, Münster.	x	x		x	
43. ,, *oblonga*, J. and K.		x			
44. ,, *subrecta*, Portlock.	x				
45. ,, *Scotoburdigalensis*, Hibbert.		x			
46. ,, *compressa*, J. and K.		x			
47. ,, *Youngiana*, J. and K.			x		
48. ,, *Armstrongiana*, J. and K.		x			
49. ,, *Bosquetiana*, J. and K.		x			
50. *Beyrichia arcuata*, Bean.					x
51. ,, *subarcuata*, Jones.	x		x		
52. ,, *fastigiata*, Jones.		x		x	
53. ,, *multiloba*, Jones.		x		x	
54. ,, *colliculus* (?), d'Eichwald.		x			
55. ,, *radiata*, J. and K.	x	x		x	
56. ,, *fodicata*, J. and K.				x	
57. ,, *tuberculospinosa*, J. and K.		x		x	
58. ,, *gigantea*, J., K. and B.	x				
59. ,, *Bradyana*, J. and K.		x			
60. ,, *ventricornis*, J. and K.		x		x	
61. ,, *bicæsa*, J. and K.				x	
62. ,, *bituberculata*, M'Coy.		x		x	
63. ,, *craterigera*, Brady.	x	x			
64. ,, *intermedia* (?), Jones and Holl.	x				
65. *Beyrichiopsis fimbriata*, J. and K.	x				
66. ,, *fortis*, J. and K.	x				
67. *Kirkbya Permiana*, Jones.		x		x	
68. ,, *umbonata*, d'Eichwald.	x	x			
69. ,, *oblonga*, J. and K.		x		x	
70. ,, *annectens*, J. and K.		x		x	
71. ,, *costata*, M'Coy.		x			
72. ,, *Scotica*, J. and K.		x		x	
73. ,, *plicata*, J. and K.		x			
74. ,, *spinosa*, J. and K.		x			
75. ,, *Urei*, Jones.		x		x	
76. ,, *rigida*, J. and K.				x	
77. *Carbonia fabulina*, J. and K.		x	x	x	x
78. ,, *Rankiniana*, J. and K.			x		x
79 ,, *subula*, J. and K.		x			
80. ,, *secans*, J. and K.		x			
81. ,, *pungens*, J. and K.		x			x
82. ,, *Bairdioides*, J. and K.		x			x

LIST OF THE GENERA AND SPECIES OF OSTRACODA RECORDED IN THE PAPERS AND MONOGRAPHS OF MESSRS. JONES, KIRKBY, AND BRADY, AS FOUND IN THE SEVERAL DIVISIONS OF THE CARBONIFEROUS STRATA OF WESTERN SCOTLAND.	Calciferous Sandstone Series.	Lower Limestone Series.	Lower Coal and Ironstone Series.	Upper Limestone Series.	Upper Coal and Ironstone Series.
83. *Carbonia Wardiana*, J. and K.		x			
84. *Bythocypris bilobata*, Münster.	x	x			
,, *Phillipsiana*, Jones & Holl, *var.*					
85. ,, *carbonica*, J. and K.		x		x	
86. ,, *sublunata*, J. and K.	x				
87. ,, (?) *cuneola*, J. and K.	x	x		x	
88. ,, (?) *cornigera*, J. and K.	x	x		x	
89. *Argillœcia æqualis*, J. and K.	x				
90. *Macrocypris Jonesiana*, Kirkby.	x	x			
91. ,, *carbonica*, Brady.		x			
92. *Bairdia Hisingeri*, Münster.	x	x		x	
93. ,, *curta*, M'Coy.		x		x	
94. ,, *plebeia*, Reuss.	x	x		x	
95. ,, *ampla*, Reuss.	x	x		x	
96. ,, *submucronata*, J. and K.	x	x		x	
97. ,, *amputata*, Kirkby.	x	x			
98. ,, *subgracilis*, Geinitz.		x			
99. ,, *brevis*, J. and K.	x			x	
100. ,, *grandis*, J. and K.	x				
101. ,, *subelongata*, J. and K.	x			x	
102. ,, *siliquoides*, J. and K.				x	
103. ,, *præcisa*, J. and K.		x			
104. ,, (?) *circumcisa*, J. and K.		x			
105. ,, *legumen*, J. and K.		x			
106. *Bythocythere Youngiana*, J. and K.		x			
107. *Cythere* (?) *superba*, J. and K.	x				
108. ,, (?) *intermedia*, Münster.	x	x			
109. *Youngia rectidorsalis*, J. and K.				x	

No. XXV.—Notes on a small group of Carboniferous Foraminifera found in the Lower Limestone Shales of the Muirkirk District in Ayrshire, with a List of the Genera and Species found in the Coalfields of Western Scotland.

By John Young, F.G.S., *V.P.*

[Read 9th April, 1891.]

The Foraminiferal group of organisms, recent and fossil, have always afforded an interesting branch of investigation to those persons who have taken it up, either for examination and study under the microscope, or for the purpose of forming a collection. This interest is much increased by the varied and beautiful forms of many of the shells when viewed externally, as also by the internal structure of the organisms when examined in transparent section under the microscope. In exhibiting to the Society this evening a series of sections and mounted specimens of Scottish Carboniferous Foraminifera from the marine limestone strata of our coalfields, I shall shortly refer, in the first place, to their mode of occurrence in the strata. In doing this I may state that they are found in nearly all the fossiliferous marine limestones and shales, but they are not always equally abundant, certain forms being often restricted to special horizons of strata and to particular localities.

When a search was first made in our limestone strata for this group of organisms by members of this Society, their attention was directed to the weathered limestones and shales in which many other forms of Microzoa, or minute life, of the limestone period had already been found. After having been carefully washed and searched, these rocks yielded on examination upwards of 30 species of Foraminifera, and I may state that, with the exception of *Saccammina Carteri*, Brady, found in the limestone, all the other forms were obtained in single specimens picked from the limestones and shales.

It is only comparatively recently that attempts have been made to grind thin transparent sections of our limestones and harder shales, which are suspected to contain Foraminifera, as by this method they are found *in situ* in the matrix in which they had been entombed. By following this plan many interesting sections have now been obtained, and to some of these I will shortly refer

later on. In the meantime it may be stated that when the late Dr. H. B. Brady, F.R.S., commenced his valuable and interesting Monograph on the British Carboniferous Foraminifera, printed by the Palæontographical Society in 1876, nearly all the genera and species submitted for his determination, and whose structures he had to work out, figure, and describe, were sent as single specimens free from the matrix, and seldom showing more than surface characters. Dr. Brady had often, therefore, to section some of these minute shells to transparency so as to obtain some knowledge of their shell-wall structure and of the arrangement of their chambers internally. These microscopical sections were not made, he tells us, without difficulty, owing to the smallness of the bodies; but this was amply repaid when it unfolded structures of such great interest, especially in their relations to other well-known types of Foraminifera. Had the same work now to be done, he would, in many cases, with the aid of the sections in existence, have been saved a great deal of labour, and he would have been delighted, I am sure, with the sight of many transparent sections of small Foraminifera which he never had the opportunity of sectioning.

To get a more correct knowledge of the structure and external characters of the fossil Foraminifera, they should always be examined by two methods, where that is possible. 1st. By the examination of their true external forms, and surface-markings, or other ornamentation, as seen on the most perfect examples of the shells. 2nd. By the examination of transparent sections of their shells, or of the rocks containing them, so as to inspect thoroughly the structure of the shell-walls, and the form of the chambers, where such exist. It is, however, not always easy to find material which will permit of both methods of investigation, and collectors have, of course, to take the rocks containing Foraminifera just as they are locally found. If they are in a weathered condition, and only fit to search after washing, unweathered specimens hard enough for grinding should be searched for, and in this way both methods of investigation may be carried out.

Foraminifera are found, as I have already stated, in nearly all the fossiliferous marine limestones and shales of both the lower and upper groups of the limestone series in Western Scotland. Indeed, there are few transparent sections of these rocks in which

examples of some of the forms may not be detected under the microscope by the practised eye. In some sections they are seen to be moderately common, and represent various genera and species; but the richest rock which I have yet examined from Western Scotland is a fine-grained limestone shale from the Muirkirk district of Ayrshire, found in connection with, or attached to, masses of the Carboniferous coral, *Chætetes septosus*, Fleming.

In order to obtain as full a knowledge as possible of the number and varied forms of the species present in this shale, I have ground to a thin transparency upwards of thirty sections, and for specimens of the coral with the shale attached, I am indebted to Dr. J. R. S. Hunter, Daleville, Carluke, and to Dr. David Forsyth, of Leeds, both members of this Society. The specimens were respectively from Durnhunch quarry, and Ashawburn, Muirkirk, and it is interesting to note that there is some difference in the distribution and abundance of the Foraminifera present in the two localities. Thus in the shale from Ashawburn, *Archæodiscus Karreri*, Brady, is the most abundant and characteristic Foraminifer present, and it may be counted by the dozen in most sections. Along with it are examples of other genera, such as *Endothyra*, *Stacheia*, *Trochammina*, and *Valvulina*, each being represented by one or more species. In the sections of this shale, there is also to be seen, under the microscope, numerous minute yellowish-brown crystals of a rhombohedral shape, each having a darker-coloured centre than its outer walls. They are so abundant that many of the sections are seen to be crowded with them, the rock being thus, in a measure, characterised by their presence. I cannot yet say what is their mineral composition, but it may be either dolomite or siderite, or a combination of these with calcite. In no other sections of Carboniferous shale have I yet met with similar crystals.

In the sections of the shale from Durnhunch quarry these small crystals are absent, but there is a greater variety of the Foraminifera. *Archæodiscus*, so plentiful in the former locality, is here somewhat rare, and its place is taken by *Endothyra* and *Textularia*, each being represented by several characteristic forms. Other genera represented are *Climacammina*, *Trochammina*, *Stacheia*, and *Valvulina*. The species belonging to the several genera from this Muirkirk shale will be found in the list given at the end of this paper.

Besides the Foraminifera, the Durnhunch shale contains examples of that curious organism first found in the Silurian rocks of the Girvan district, and named *Girvanella* by Prof. H. Alleyne Nicholson and R. Etheridge, jun., in their "Monograph on the Silurian Fossils of the Girvan district," p. 23, where it is placed with the Foraminifera. In my sections of the Muirkirk shale there are at least two varieties, one having much more minute tubes than the other; both are found in the shale in the form of small twisted bundles. There are also seen in the sections fragments of larger tubes having moderately thick walls, and with the same structure as that of the other arenaceous Foraminifera present. These tubes in longitudinal section are seen to taper gradually to one end, but are not chambered within. They may therefore belong to an uncoiled form of *Trochammina*, like that of *T. filum*, Schmid, figured and described by Dr. Brady from the Permian formation. This form consists, he states, "of a long tube of gradually increasing diameter, irregularly bent, and often partially coiled at its commencement." Should my conjecture prove correct, it will add another species of *Trochammina* to our Scottish Carboniferous list.

I have only further to remark respecting the Muirkirk Foraminifera, that all the forms are exceptionally well-preserved as regards their internal structure; in fact they are in better condition than those found in our purer limestones, which have, in many cases, lost much of their finer structure through crystallization of the limestone. I may also add, regarding my sections of limestone shale, that Foraminifera are not the only organisms they contain. Scattered throughout the sections there are the remains of Ostracoda, with fragments of various species of Polyzoa, Corals, Crinoids, Brachiopods, univalve and bivalve shells, and sometimes small teeth and scales of fish. We have, therefore, in this shale, all the preservable finer organic débris of a portion of an old sea-bottom of the lower Carboniferous limestone period, the fragments being wonderfully well-preserved when we consider the great antiquity of the rocks in which they are found.

Postscript.—Since the period when the foregoing paper was read to the Society I have been giving some attention to another Foraminiferal form found somewhat plentifully in one of the

limestone shales at Muirkirk, and less abundantly in a few of the other Carboniferous limestones of Western Scotland, and which is neither figured nor described in Dr. Brady's Monograph. This form is found to consist of small, evenly rounded spheres, and sections of spheres, of various shapes and sizes, showing clear evidence of having once been clustered together, as in the recent Globigerinidæ. When thin transparent sections of these spheres and their segments were examined under the microscope, and compared with similar sections of a deep-sea *Globigerina* ooze, which I have prepared, they were seen to be very much alike both as to size and form, as well as in the thickness and structure of their shell-walls. The only point of seeming difference is, that in the Carboniferous form the various segments which formed the clusters are now in a more broken-up and scattered condition in the surrounding sediments than is seen in the clusters from the deep-sea deposit. Separated segments of the latter are, however, seen in the sections from the recent deposits, with exactly similar appearances to those found in our limestone strata.

The Carboniferous form may be briefly described as consisting of complete spheres, which appear as perfect circles in the sections when they happen to be cut transversely along certain lines. They are also seen as segments of spheres of varying size and form which show, on one edge, where they were attached to other spheres or segments of the clusters of which they once formed part. These circles and segments are seen to be uniformly thin-walled, and generally show a dense, sub-arenaceous shell-structure when looked at under the microscope by transmitted light. From these characteristics they are easily distinguished from any of the other Foraminifera, which are thicker walled as well as different in form. The spheres and segments are often filled with a clear, structureless calcite; when this is not the case their inner walls are coated with some mineral deposit, or filled with the sediment which formed the rock matrix.

Dr. Brady, in his Monograph, makes no reference to *Globigerina* as being found in Carboniferous limestone strata, but states that *Textularia*, and one or two other forms found in the same strata, are now placed in the Globigerinidæ group, as they apparently possess the same kind of shell-structure, though they differ in

form from the recent *Globigerina*. So far, therefore, as form and other characters go, I am inclined to place this Carboniferous form provisionally in my list with *Globigerina*, as that genus, so far as known to me, is the only one which possesses characters which agree most closely with the new form. I leave its relationship to recent and living species for future determination.

In concluding, I have only further to remark that this interesting Carboniferous representative of a deep-sea Foraminifer which is still living in our seas is always associated in the limestones with other species of the group, some of which are also allied to recent living genera. The following are a few of the chief localities in which it is found, viz., Durnhunch quarry, Muirkirk, in the limestone shale; Trearne and Dockra, Beith, in the limestone; Baidland and Law quarries, Dalry, in the limestone; Campsie, in the main limestone, where it is found with *Saccammina*, a form still living. I have also found it moderately common in sections of the limestone from Closeburn quarry, Dumfriesshire, the strata there belonging to the Calciferous sandstone series of the lower Carboniferous formation.

Species from Muirkirk Shale.	LIST OF CARBONIFEROUS FORAMINIFERA FROM WESTERN SCOTLAND.	Lower Limestone Series.	Upper Limestone Series.	LIST OF CHIEF LOCALITIES WHERE SPECIMENS HAVE BEEN FOUND.
	Saccammina Carteri, Brady.	x		Braidwood, Carluke. Campsie main limestone.
*	*Climacammina antiqua*, Brady.			Brockley. Muirkirk.
*	*Trochammina incerta*, (d'Orbigny).	x	x	Robroyston. Muirkirk.
*	,, *centrifuga*, Brady.	x	x	Robroyston. Muirkirk.
	,, *annularis*, Brady.	x		Capelrig, Kilbride.
	,, *gordialis*, P. and J.	x		South Shiells, Kilbride.
	,, *pusilla*, (Geinitz).	x	x	Trearne, Beith. Gare, Carluke.
	,, *Robertsoni*, Brady.		x	Gare, Carluke.
*	*Valvulina palæotrochus*, Ehrenberg.	x	x	Robroyston. Brockley. Muirkirk.
*	,, ,, var. *compressa*, Brady.	x	x	Gare, Carluke. Brockley, Muirkirk.
*	,, *Youngi*, Brady.	x		Brockley. Trearne. Dalry. Muirkirk. Campsie.
	,, ,, var. *contraria*, Brady.	x		Brockley. Trearne. Beith.

Species from Muirkirk Shale.	LIST OF CARBONIFEROUS FORAMINIFERA FROM WESTERN SCOTLAND.	Lower Limestone Series.	Upper Limestone Series.	LIST OF CHIEF LOCALITIES WHERE SPECIMENS HAVE BEEN FOUND.
*	*Valvulina decurrens*, Brady.	x	x	Gare, Carluke. Brockley, Muirkirk.
	,, *plicata*, Brady.	x		Calderside, Blantyre. Hairmyres.
	,, *rudis*, Brady.	x		Headsmuir, Carluke.
*	*Endothyra Bowmanni*, Phillips.	x	x	Calderside. Trearne. Dalry.
*	,, *ammonoides*, Brady.	x	x	Muirkirk. Gare, Gillfoot, Carluke.
*	,, *globolus*, (d'Eichw).	x	x	Muirkirk. Gillfoot. Braidwood.
*	,, *crassa*, Brady.	x	x	Muirkirk. Brockley. Muirkirk.
*	,, *radiata*, Brady.	x	x	Robroyston. Gillfoot. Brockley. Muirkirk.
*	,, *macella*, Brady.	x		Brockley. Muirkirk.
*	,, *ornata*, Brady.	x		Brockley. Muirkirk.
	,, ,, var. *tenuis*, Brady.		x	Robroyston. Barmulloch.
	,, *subtilissima*, Brady.	x		Brockley.
	Nodosinella concinna, Brady.		x	Belston Burn, Carluke.
	Stacheia marginulinoides, Brady.	x		Brockley.
	,, *fusiformis*, Brady.	x		Belston Burn. Brockley.
	,, *pupoides*, Brady.	x		Brockley. Hairmyres.
	,, *acervalis*, Brady.	x		Hairmyres. Gare, Carluke.
	,, *congesta*, Brady.	x	x	Belston Burn. Carluke.
*	,, *polytrematoides*, Brady.	x	x	Gare. Braidwood. Hairmyres. Muirkirk.
	Lagena Parkeriana, Brady.		x	Belston Burn, Carluke.
	,, *Howchiniana*, Brady.		x	Belston Burn, Carluke
*	*Textularia gibbosa*, (d'Orbigny).	x		Brockley. Muirkirk.
*	,, *eximia*, (d'Eichw).	x		Brockley. Muirkirk.
*	,, (undetermined species).			Muirkirk.
	Bigenerina patula.	x		Headsmuir, Carluke.
*	*Archæodiscus Karreri*, Brady.	x	x	Craigenglen. Brockley. Muirkirk. Belston Burn.
*	*Girvanella*, (sp.) (Nich. and Ether.).	x		Muirkirk. Law quarry, Dalry.
	Haplophragmium rectum (?) Brady.	x		Hillhead quarry, Beith.
*	*Globigerina*, (sp.)	x		Beith. Campsie. Dalry. Muirkirk.

No. XXVI.—Note on a "Wash-out" in a Shallow Pit of the Drumshangie Coal Company, near Airdrie. By Robert Dunlop.

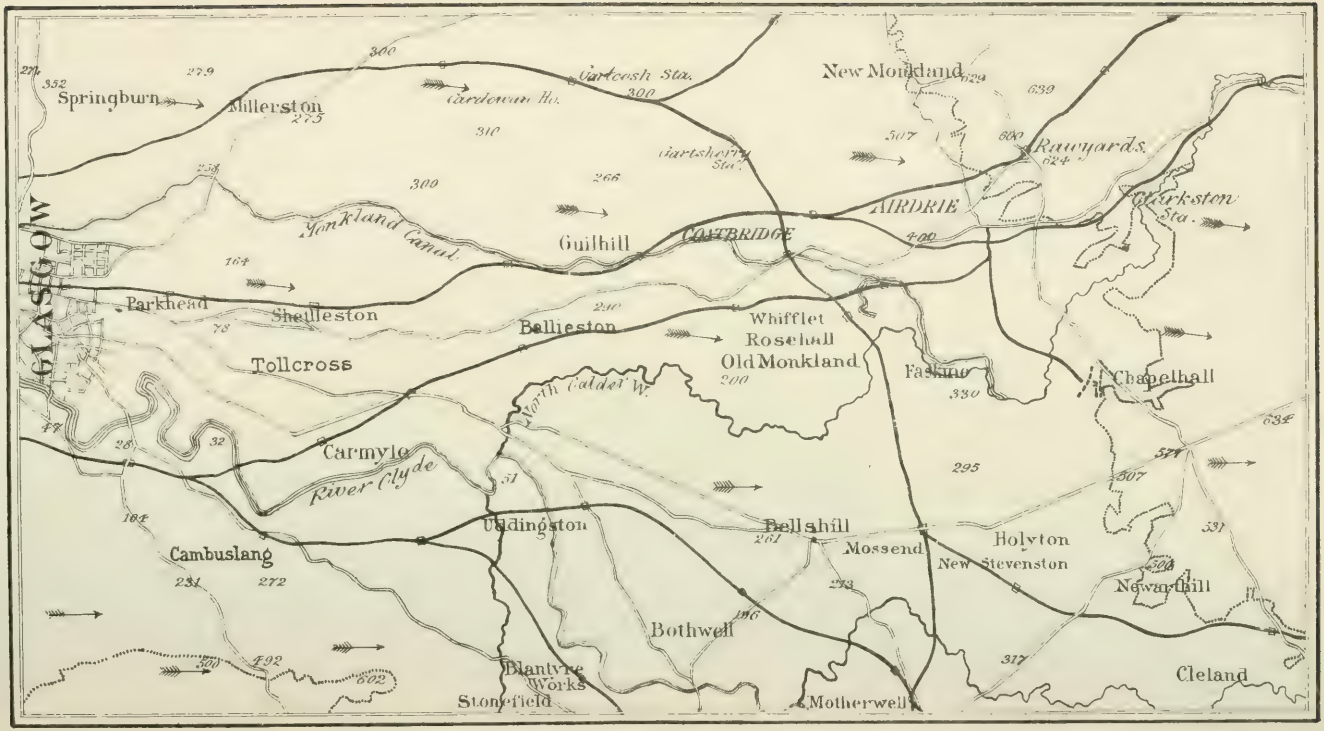
[Read 9th April, 1891.]

Two miles from Airdrie, and in a north-easterly direction, the minerals are at present being wrought by the Drumshangie Coal Company. In the month of November, 1890, they put down a shallow pit, 36 feet deep. At a depth of 33 feet from the surface the Upper Drumgray coal, 12 inches thick, was met with.

On examination, the coal was found to be badly burned and very sulphurous, but in the hope that it would improve in quality and in thickness a mine was driven into it. To the surprise of the miners the metals disappeared, and in their place were found rounded stones, having the appearance of being thoroughly water worn, and of all sizes, ranging from many hundredweights downwards. They consisted of sandstone, ironstone, faikes, shale, coal, gas coal, and in fact representatives of nearly almost all the ordinary carboniferous rocks known in the district. There were also a few strangers found amongst the boulders, and specimens of these are laid on the table.

A most interesting point in this section is that the material between the rounded stones is not the ordinary Boulder-clay but a very pure fire-clay, which, however, became more gravelly and sandy at the bottom. After the rounded stones had been washed by the rain and weathered, I went back, and for some hours examined all the smoothed stones to see if I could detect any scratches, but I could see none. In ordinary Boulder-clay there is no difficulty in finding any number of striated stones. Another point which may be noted, and of which I have never known a previous occurrence, was the presence of fire-damp in the Boulder-clay, and to such an extent that the men had to work with safety lamps. This is the more remarkable, as in the coal seam, and indeed in all the seams wrought by the Drumshangie Coal Company in the neighbourhood, fire-damp is practically unknown.

I have thought it best to bring these particulars before the Society to-night, believing it is right to put all such phenomena on record, so that they may be available if required at some future date. The collection of such points may one day help to explain various matters now imperfectly understood.



SKETCH MAP OF DISTRICT, GLASGOW TO CHAPELHALL.

Figures indicate feet above sea-level. Dotted line = 500 feet. Arrows indicate direction of ice-flow.

CARTER & PRATT, LITH.

No. XXVII.—On the Alleged Proofs of Submergence in Scotland during the Glacial Epoch.—I. Chapelhall, near Airdrie. By Dugald Bell, F.G.S. With a Map.

[Read 10th March, 1892.]

One of the most interesting questions in recent geology relates to the degree of submergence which took place in Britain during the Glacial epoch. That some submergence did occur is admitted, and seems clearly proved; but *how much*, has been matter of prolonged discussion and difference of opinion among geologists. Till recently, a submergence of from 1500 to 2000 feet was freely affirmed, with regard to parts, at least, of the British Isles. This affirmation rested on certain "high-level shelly gravels" found in Wales and on the borders of Wales, and on one or two Irish mountains. It was assumed, of course, that these shelly gravels, as well as similar gravels without shells extending several hundred feet higher, had all been deposited at these heights by the sea. Gradually, however, this conclusion came to be doubted. First, the shell-less gravels were discarded as devoid of proof—the mere fact of their being gravels, more or less evenly stratified, being far from conclusive as to their being laid down by the sea. The shelly gravels themselves were next called in question, and were found to present so many doubtful features—in their detached and sporadic character, in their being largely made up of far-travelled and striated materials, and in the mixed and broken nature of their shelly contents—that the conviction grew up that they were not really in place, but had been transported somehow, probably by ice, from a former bed of the sea at a lower level. As similar instances of the transport of marine organisms by ice became known in increasing numbers this conviction strengthened, and it was corroborated by observations on the glaciation of the surrounding neighbourhood and of the country generally, as well as by comparison with what is known regarding the glaciation of other parts of the northern hemisphere. The researches and observations of Belt, Goodchild, Clement Reid, Carvill Lewis, and others,* have tended powerfully to establish the conclusion that these "high-level shelly drifts" are really of glacial origin,

* *Nature*, May, 1874; *Geol. Mag.*, 1874, p. 496; *Ib.*, 1881, p. 235; *Reports, Brit. Assoc.*, 1886-87; *Transactions*, vol. ix., part 1, p. 100.

so far as their present position is concerned. Hardly any geologist of mark now stands up for this "great submergence." Here and there, it is true, some doughty champion, unaware apparently that the position has been abandoned, steps bravely forward to defend it. But, speaking generally, we may say that this "great submergence" is a day-dream of the past, and "lives no longer in the faith of reason."

But there are other degrees of submergence—minor, yet very considerable—usually admitted and taught by geologists, which we still venture to think are far from being satisfactorily proved.

The first of these is the submergence of between 500 and 600 feet supposed to be indicated by a bed of shelly clay recorded to have been found at Chapelhall, near Airdrie, about 11 miles east of Glasgow. There is certainly a great difference between a submergence of 1360 and one of 526 feet; and it is quite possible there may be good reasons for doubting or disbelieving in the one which do not apply to the other. But it appears to us that even this second or much smaller submergence is by no means clearly made out.

I. *Accounts imperfect and doubtful.*—Our first remark on this instance at Chapelhall is that very little is really known of it—far too little to found so much upon it as has been done. May we ask attention to a brief narrative of what has been recorded regarding it?

(A) This "deposit" was first brought into notice by Mr. Smith of Jordanhill, in a paper read to the Geological Society in 1850, and re-published in his well-known little volume of "Researches in Newer Pliocene and Post-Tertiary Geology," in 1862. "The shells," Mr. Smith states, "were discovered by Mr. James Russell, an operative miner, in digging a well." Mr. Russell informed Mr. Smith that "at the depth of 14 feet from the surface he came to a bed of brick clay containing the shells." The surface of the ground here Mr. Smith found to be 524 feet, and, therefore, the shelly clay was 510 feet above the sea. At the time of his visit Mr. Smith saw part of the "superincumbent matter which had been thrown out, lying at the mouth of the well;" and this, he says, was "unquestionably true till," and contained, among other stones, "a small granite boulder," which must have been brought from a distance of about 60 miles to the N.W. He adds, "Mr.

Russell states that after passing through the shelly bed of brick clay he came again to the till"; proving that there had been "more than one deposition of the till or Boulder-clay."

It does not appear, then, that Mr. Smith either saw the shelly clay or took the shells from it himself; the latter he seems to have got either from Mr. Russell, or from Mr. John Craig, a mining engineer, whom Mr. Russell had first seen, and who informed Mr. Smith of the "deposit," and accompanied him to the locality. These shells—their number is not stated—seem all to have been of one species, *Tellina calcarea* (or *T. proxima*)—"an Arctic species," remarks Mr. Smith, "extremely abundant in the Clyde Pleistocene beds." The deposit was accordingly described by Mr. Smith as "a bed of the *Tellina*."

This is really all that can be gathered from Mr. Smith's paper. It rests throughout on the authority of Mr. Russell.*

(B) Sir Archibald Geikie, in the preparation of his valuable Memoir on "The Phenomena of the Glacial Drift of Scotland," † visited the spot, also under Mr. Russell's guidance. He describes it as situated "on the crest of a ridge which, rising high above the surrounding country, commands an extensive view across the lower part of the basin of the Clyde. On the water-shed of this high-lying ridge a well was sunk some years ago, and while the excavations were in progress the shells were found." Sir A. Geikie then gives particulars corresponding with those stated by Mr. Smith, adding that the lower till was here "about 24 feet thick, and lay directly on the Carboniferous strata of the district. The brick clay, at its thickest part," he continues, "measured 2 feet 1 inch in depth, but thinned away rapidly on every side so as to allow the

* "Researches," pp. 139-142. Of course in our remarks we do not wish to cast the slightest doubt on Mr. Russell's testimony as to the fact of the shells being found where he stated; all we say is that he does not seem to have examined the clay very minutely—certainly not with the care and minuteness now considered desirable, in view of the many questions which have arisen regarding these shelly clays; and that, so far as appears, neither Mr. Smith nor any other geologist had an opportunity of doing so personally. It is incredible that Mr. Smith, if he had seen the clay itself, should not have said so, and only mentioned the "superincumbent matter"; incredible also that, if he had had the opportunity, he should not have examined the clay for other organisms besides the *Tellina*, and stated that he had done so.

† *Transactions*, vol. i., part 2, 1863.

upper and lower till to come together. From a number of additional wells, sunk on purpose, Mr. Russell ascertained that the clay lay in a hollow of the undermost till, and that this hollow measured about 19 feet long by about 5 feet broad. Pits which were dug beyond the boundary of this little trough showed a great depth of the usual till, but without a trace of brick clay. The shells," adds Sir Archibald, "consisted entirely, I believe, of *Tellina proxima*. Usually the specimens were broken, but a good many were taken out entire, with both valves together." *

Sir Archibald thus adds several particulars to Mr. Smith's account; but, excepting his observations on the surface, which are interesting and valuable, these particulars are still all derived from Mr. Russell. The well was built up; the clay was not visible; but all that could be learned regarding it confirmed its local and limited character.

(C) About the same time as Sir A. Geikie's visit, or apparently shortly before it (though their account was later in being published), Dr. Crosskey and the late Dr. Bryce visited the locality and made some observations, the results of which were communicated by Dr. Crosskey in a paper to the Geological Society in January, 1865. † Dr. Crosskey alluded to the perplexing nature of the deposit as occurring "intercalated between two masses of Boulder-clay," and his more immediate object was to examine "whether the superincumbent matter was without doubt the true till," as Mr. Smith had pronounced it to be. He thought it was not, but that the upper clay might have been "the wash from a ridge of true Boulder-clay which rises above it, and against the slope of which it rests." This view, however, seems to be untenable. But, leaving this in the meantime, we note that at Dr. Crosskey's and Dr. Bryce's suggestion Mr. Russell "sank a fresh well, 7 yards from the old one," the section in which was entirely different, and showed *no* shelly clay.

Old Well.		New Well.
Upper Boulder-clay, - -	14 ft., -	5 ft. 3 in.
Clay with Shells, - -	2 ft.	
Boulder-clay (thickness not stated), -		9 ft. 6 in. (not pierced through.)

We may take it that this well was sunk before Sir A. Geikie's

* *Op. cit.*, pp. 58-9.

† *Quarterly Journal of the Geological Society*, vol. xxi.

visit; for, by that time, the information was that "a number of wells" had been sunk, and that the shelly clay had been ascertained to be "about 19 feet long by 5 broad." Of course, had this been known when Drs. Bryce and Crosskey were on the spot, there was no use in sinking a new well "7 yards from the old one."

The thickness of the lower Boulder-clay, also, which was quite indefinite at the time of Dr. Crosskey's visit, seems by the time of Sir A. Geikie's to have been ascertained to be "about 24 feet thick."

The only point on which Dr. Crosskey's account goes beyond either Mr. Smith's or Sir A. Geikie's, is in stating that besides the *Tellina calcarea*, "*Cyprina Islandica*, and a large *Balanus* are found in the clay." In one sense the occurrence or non-occurrence of these organisms in the clay is of no great consequence, as the *Tellina* by itself is sufficient to mark the deposit as glacial. But it is a curious point how, about fourteen years after Mr. Smith's account was first written, and a year or two after it was re-published in book form, these additions came to be made to the organic contents of the clay. The well does not appear to have been re-opened in the interval; none of the clay seems to have been retained for further examination; new wells were sunk in vain to find it again, and not one of the observers we have been quoting from states he ever saw it. Whence, then, came the *Cyprina Islandica* and the *Balanus?* *

* We understand Dr. Crosskey received the particulars given in his paper from Mr. Russell. How, then, was Mr. Russell able to say so much more about the clay to Dr. Crosskey than he had said to Mr. Smith? As already said, we make no imputation against Mr. Russell's good faith and general accuracy; but mistakes will sometimes happen; and it is, at least, a coincidence that Mr. Smith in his paper (which, at the date of Dr. Crosskey's visit, had lately been republished), a few lines after describing the Chapelhall till, goes on to speak of organic remains sometimes found in the till generally, and adds, "upon one occasion I found broken and water-worn fragments of shells irregularly dispersed in it, amongst which I recognised the massive hinge of *Cyprina Islandica*, and the stem of a large *Balanus*" ("Researches," p. 141). A hasty, or not very exact, or, for the moment, inattentive reader, might make the mistake of supposing that here Mr. Smith was still referring to the Chapelhall clay, instead of the till in general; though, of course, Mr. Russell would have less excuse than most men in making such a mistake, seeing it was he who first supplied Mr. Smith with his information. In whatsoever way these additions to the fauna of the Chapelhall clay came to be made, they are to be found repeated, generally on Dr. Crosskey's authority, by various writers down to the present time (see, for example, Dr. James Geikie's "Great Ice Age," p. 163).

We have entered into these particulars simply to show how imperfect and unsatisfactory, in many respects, is all we know of this Chapelhall deposit.*

From our own observation we can corroborate Sir A. Geikie's description of the locality. The well is situated at the upper end of the village of Chapelhall, behind the cottage once occupied by Mr. Russell, who died about twelve years ago. Its position is on one of the highest of those long ridges of Boulder-clay which abound all over the district, extending approximately in a direction from N.W. to S.E., and it is not far from the summit of the ridge. It seems impossible, therefore, that the upper till could be a "wash down" from a higher ridge of "true Boulder-clay," as Dr. Crosskey suggested. Had it been in the hollow between two such ridges, this would have been more probable. But the fact is as stated, its position is high, on the very back or crest of the ridge, conspicuous all round; and there is not the slightest evidence of any "slip" of the Boulder-clay near the spot.

VIEW OF CHAPELHALL. × *Cottage with Well.*

But we need not dwell longer on this, seeing that the upper is generally acknowledged to be as true till or Boulder-clay as the lower.

At present the well is about 16 feet deep (it was originally 2 feet deeper, but has been filled in at the bottom); and, as might be expected from its situation, the supply of water is not very copious, and in a continuance of dry weather almost ceases, or falls very low. At such a season, if the well were run dry, an effort might be made to reach the "shelly clay" again, and bring

* In a note received lately from the veteran geologist, Mr. David Robertson, he says, "It is a remarkable fact that no other shells were found associated with the *Tellina* in the Chapelhall deposit. I have never found it without finding others with it, and often it was far outnumbered by other species."

up a portion of it for further examination.* This is, of course, desirable, seeing that so little is known of it; that though mentioned in almost every geological work for the last forty years, it would seem that no geologist since Mr. Russell's day has set eyes upon it; and that though carefully searched for all round the neighbourhood—in railway cuttings, shafts, quarries, and other openings,—it has not been met with since Mr. Russell dug his well, and built it round, forty-two years ago.

II. *Difficulties in regard to it and other High-level Deposits.*—But even supposing the clay were found again in the same spot, however satisfactory this might be in some respects, it could hardly alter, or add to, the fact that here, at the very utmost, we have a limited patch or strip of shelly clay imbedded in the till or Boulder-clay at this height above the sea. The question then arises, Is this sufficient to sustain the immense pile of inferences that has been built upon it—first, a period of extreme glaciation, when "the great central valley of Scotland brimmed with glacier ice;" then a period of "milder conditions," and a submergence of the land to a depth of between 500 and 600 feet beneath its present level; then a re-elevation of the land, and "another mighty ice-sheet again overflowing it?"† Restricting ourselves at present to the submergence, we ask, Is this patch of shelly clay sufficient to prove a submergence of between 500 and 600 feet? Some have thought so. "Evidently," says one esteemed writer, "the shelly clay at that place marks an old sea-bottom, when the sea rose not less (indeed, certainly more) than 526 feet above its present level."‡ We venture to think it is not sufficient without further confirmatory evidence, which, if the conclusion were true, might reasonably be looked for, but of which there is a very striking lack and deficiency; also that, as in the case of Moel Tryfaen, the theory of a purely marine origin for the deposit entails more and greater difficulties than it solves.

(1) *Its Limited Extent.*—If this Chapelhall clay were in the true sense a shell-bed, marking the former level of the sea, might we not expect to find remains of it in many localities all over the district and neighbourhood, and in other parts of the country as well as here?

* We are in hopes of this being done.

† "Great Ice Age," pp. 175-6.

‡ *Ib.*, p. 175.

Dr. J. Geikie justly points out that "when a free ocean flowed over the site of the district in question"—supposing it did so—"a very large part of the Scottish lowlands would be submerged. The sea would wash the base of the Kilsyth hills on the north, and towards the south would extend up the Clyde valley as far at least as Hazelbank, a few miles below Lanark."*

In short, the sea would rise to a considerable height along the Campsie and Kilsyth hills on the one hand, and the Ayrshire, Renfrewshire, and Lanarkshire hills on the other; as well as along every range of hills all over the kingdom, unless the submergence were restricted to this district, which is not maintained.

Now, if there was such a submergence, the reason commonly assigned for the paucity and disappearance of all traces of it is the "clearing out" effected by the "second" or subsequent glaciation. But, as we have tried to show elsewhere,† this is a most inadequate reason, and might account for the absence of such traces in a few localities, but not for their disappearance all over the country. There are special features in this district which make it extremely unlikely. These hills to which we have referred as bounding the midland valley are characterised by numerous bends and inlets, and are intersected by transverse valleys, in which marine deposits would be most likely to accumulate, and where they would most likely be preserved. As Dr. Geikie well states, when referring to the beds of sand and gravel—old stream-deposits—often found intercalated in the Boulder-clay, "During the glacial period, the ice-sheet which followed the lines of the principal valleys must frequently have crossed the lateral and subsidiary valleys nearly at right angles. In the main valleys the glacier would exert its full influence, but it would not be able to do so in the narrow lateral valleys and ravines; the ice and till would merely topple into the glens referred to and gradually choke them up, and the main mass of the glacier would then pass on over the whole. In such narrow glens, then, any silt, sand, or gravel that had gathered during the temporary absence of the ice-sheet would not be so likely to be ploughed out when the ice returned as the similar materials which had accumulated in those broader and more open valleys where the ice would have full freedom to move and exert its erosive power."‡

* *Op. cit.*, p. 175. † *Transactions*, vol. ix., part 1, p. 100.
‡ "Great Ice Age," pp. 133-4.

Why, then, if there was a submergence to the extent alleged, are such high-level shell-beds not found in scores of the lateral glens, valleys, and ravines which were comparatively sheltered from "the erosive power of the old glaciers," and all evidence of such submergence left, not in a sheltered position, but in a most unlikely place—on the summit of a high exposed knoll or ridge "nearly in the centre of that broad tract of lowland country" which it is admitted was swept by the old glaciers, and formed one of their main pathways and outlets? That is one difficulty.

It may be objected that this is an argument from a negative, which is always inconclusive. But in one sense there is a positive element in it—in a part of the country so much cut up and dug into, if such traces have not been found, we may safely conclude it is because they are not there.

(2) *Absence of Marine Organisms in the Overlying Deposits.*—Another difficulty is, if the "second glaciation" ploughed up and removed the shell-beds formed during the submergence—as it must have done to a great extent—why do we not find remains of these scattered throughout the upper Boulder-clay? We have instances of this in the "shelly tills" that are found in various parts of the kingdom, and in other parts of the world—wherever the ice-sheet is known to have passed over what had been a sea-bottom.

When the prolonged period of submergence, during which the broad midland valley was an ocean sound, passed away, and the "mighty ice-sheet again overflowed the land," should we not find abundant traces of the sea incorporated with the overlying Boulder-clay, its latest work? "During the last cold period," says Dr. Geikie, "the confluent glaciers cleared out the marine deposits laid down in preceding interglacial times, and incorporated them with their *moraine profonde*. This is the origin of most [all?] of our shelly tills or Boulder-clays." *

Again, "We know that the latest ice-sheet which overflowed Scotland did enter the sea and mix up marine deposits with its moraine. Thus it was that the silt and shells lying on the bed of the Minch were pushed up over the north end of Lewis, and so also was it that Caithness received the spoils of the Moray Firth." † Why, then, is this "upper Boulder-clay" of Lanarkshire—the ice

* *Op. cit.*, p. 329. † *Ib.*, p. 390.

forming which must have passed over miles and miles of former sea-bottom (if the alleged submergence were a fact)—why is it not charged with marine remains?

On this point we cannot do better than quote Dr. Geikie's own words, "While there is proof to show that immediately before the appearance of the last ice-sheet, Scotland was submerged to a depth of more than 500 feet, yet the upper Boulder-clay of that country rarely contains broken shells, save in maritime districts. Why, we may ask, does not the upper Boulder-clay of the Central Lowlands (a great proportion of which must have been submerged before the last ice-sheet overflowed Scotland) contain broken shells, and afford other indications of the latest confluent glaciers having occupied the bed of the sea?"

That is the question, as Dr. Geikie well puts it. What is the reply? "That is a very hard question to answer, and I fear we must wait some time yet for an adequate solution of the difficulty."* We think it will be admitted that this is not satisfactory. If we adopt a theory, and find that it lands us in an inexplicable difficulty, to say simply that "we must wait some time yet for a solution" is surely very unsatisfactory, and should lead us at least to re-examine the theory, or inquire whether we are really shut up to its adoption.

(3) *Highly Arctic character of Shells found in the Clay.*—Another difficulty presents itself. It has been supposed that these shells were deposited in a "mild interglacial period"—in one of such periods when "the great ice-sheet disappeared from the low grounds and shrank into a series of local glaciers among the mountain regions;" nay, "which there is no evidence to show might not have been warm enough at times to cause all the ice and snow to disappear from the country."† Dr. Geikie, for example, dwells on this point, impressing upon the minds of his readers the long periods implied in such great climatic changes, and stating that it seems "not unreasonable to infer that the comparatively mild and genial periods, of which the interglacial beds are memorials, may have endured as long as these Arctic or glacial conditions which preceded and followed them."‡ We must not enter here upon the discussion of these so-called "mild and genial interglacial periods." We only remark that if such a submergence did take

* "Great Ice Age," p. 390. † *Ib.*, pp. 155, 157. ‡ *Ib.*, p. 158.

place, it would certainly, so far as we can see, be accompanied by a great amelioration of the climate. It seems clear that the greater or less height of the land would tell powerfully on the climatal conditions by increasing, or diminishing the extent of high land, and by shutting off, or more freely admitting, the ocean currents, which are the great distributors of warmth and equalisers of temperature. In short, there seems no reason to doubt that any submergence of the land is, *pro tanto*, in favour of a mild and equable climate.*

Now, we should naturally expect that the organic remains found in deposits laid down during these "long, mild, and genial" interglacial periods—especially if accompanied by physical changes favourable to the maintenance and diffusion of such mild conditions—would indicate more or less clearly the great change of temperature which had taken place, and would present a distinctly more southern *facies* than those which had been laid down under colder conditions. I need not remind my present audience of the close connection there is between temperature and species, and that this is especially the case with regard to the mollusca. Some species are so intolerant of cold that they barely touch the southern coast of Britain; and others are so averse to warmth that they scarcely reach our northern shores,—so nice is their dependence on conditions of temperature, and their restriction to certain climatal areas.† Shells have thus been taken to be most sensitive and accurate indicators of the prevailing temperature. In illustration of this, several geological writers have shown that some shell-beds on our eastern coast indicate colder conditions than those of the Clyde valley; and they account for this by saying that "the North Sea, cumbered with ice from Scandinavia as well as from Scotland itself, would in all probability have a lower temperature than the freer ocean"—though it was certainly far from being free of ice—"that washed the western sea-board." If "therefore it is not surprising that this difference of temperature should have taken effect and influenced the distribution of the fauna,"‡—much more,

* Those geologists, however, who most favour submergences (for they often suppose *several* of them) don't always observe this connection in their scheme of events; they frequently put the milder condition and the retreat of the ice *first*, and *then*, after a considerable interval it may be, the submergence.—"Great Ice Age," pp. 184, 329, 397, 410, 563.

† See, *e.g.*, Miller's "Sketch-Book of Popular Geology," pp. 329, 330.

‡ "Great Ice Age," p. 265, note.

as it seems to us, should we expect this difference to appear in beds deposited during a long, mild interglacial period, when all the land of the country was lowered by 500 or 600 feet, and when a broad ocean sound filled the central valley.

What, then, is the nature of these shells found on this supposed sea-bottom near Airdrie, laid down at the very climax of such an interglacial period? Keeping by all we know—the *Tellina calcarea* —it is one of the most distinctively Arctic shells found anywhere in our glacial deposits, a shell marking extremely cold conditions, "not yet found living in the British seas, but abundant on the coasts of Greenland, boreal America, &c." (Miller), "living in the Arctic seas, not known as a living British shell" (A. Geikie). Is there really any value in shells as indicators of the prevailing temperature in any formation, if a "bed" of this *Tellina calcarea* is to be taken as marking a "mild interglacial period?" *

So long as anything like the present distribution of sea and land prevailed (and it is not contended that there was any material

* Dr. James Geikie alludes to this difficulty. He says, "I have spoken of these shell-beds [Chapelhall and others] as interglacial deposits, although their fossils indicate the pressure of a much colder sea than now flows round the British coast, simply because they are links in the chain of evidence which goes to show that the intense cold of the glacial epoch was interrupted by more or less prolonged intervals, during which milder conditions of climate prevailed." We confess ourselves unable to see how this Chapelhall bed, of strongly Arctic character, though deposited during a time of great submergence, can in any way serve to show the prevalence of "milder conditions of climate." Its evidence seems to be quite the other way. Dr. Geikie continues, "A very little consideration will suffice to convince us that, however cold the climate may then have been, Scotland could not by any possibility have presented such an intensely Arctic aspect as when the ice-sheet was at its thickest" ("Great Ice Age," p. 175). But was not this simply because there was less of it left to present any aspect at all? Judging from what is known of the habitats of this shell, the lands adjoining the seas in which it lived would be covered with ice and snow, and the seas themselves almost constantly laden with floating ice. And if this was the case in our country, even when it was submerged to a depth of between 500 and 600 feet, we fail to see the proof of an amelioration of climate.

[We trust our numerous references to Dr. Geikie's work will be excused, as it is the leading work on the subject. But fifteen years is a long time in Glacial geology (we mean in the study of it) and the numerous points of divergence that are now cropping up suggest whether it is not time for a *third* and *revised* edition?]

difference in that respect during the Glacial epoch) there must always have been more or less of a warm ocean current from the S.W., reaching the shores of northern Europe in exchange for the cold current from the N.E., flowing southern along the shores of North America. This is in accordance with the great system of atmospheric and oceanic circulation, which again is a result of the greater heat of the tropics, and of the earth's rotation on its axis.*

It seems incredible, therefore, that there should be a submergence of the British Isles to the amount of between 500 and 600 feet—all the high grounds lowered and circumscribed to that extent, and the sea so much more freely intersecting the land—without a far greater amelioration of climate than is indicated by these Chapelhall shells. In other words, the nature of the organisms seem to be a further difficulty in the way of believing that this clay was actually deposited by the sea during a period of submergence. And these remarks, of course, apply to all so-called "high-level Arctic shell-beds." The higher the level, the greater the double improbability of their being (*a*) true "shell-beds," and (*b*) of Arctic species.†

* Nay, so similar in some respects to those now existing were the conditions during the Glacial epoch—the distribution of sea and land, the general configuration of the surface, and the prevailings winds and currents—that the areas of maximum precipitation seem to have been virtually the same as at present,—so that "the marks of ancient glaciers are most decided where the rainfall is now heaviest" (Jamieson, *Quar. Jour. Geol. Soc.*, 1874).

† Since this was read we have been reminded of the following passage in a paper by Sir William Thomson (Lord Kelvin) on "Geological Climate":—"A thousand feet of depression would submerge the continents of Europe, Asia, and America for thousands of miles from their present northern coast-lines; and would give, instead of the present land-locked and therefore ice-bound Arctic sea, an open iceless ocean, with only a number of small steep islands to obstruct the free interchange of water between the North Pole and temperate and tropical regions. . . . Now what must be the climate of a small island in an open iceless circumpolar sea? Temperate and quite free from frost except in hollows, we may, I think, safely answer" (*Transactions*, vol. v., part 2).

Of course, what his lordship here says of a depression of 1000 feet (which was taken simply by way of illustration) is true also in measure of a depression of 500 feet. Indeed, it is to be remembered that the principal change in the extent and contour of the land would be caused by the submergence of the *first 500* feet.—We have great pleasure in citing this passage as strongly corroborative of the argument just stated.

(4) *Was the Submergence caused by Subsidence?*—These observations appear to hold good whatever theory we adopt as to the cause of the supposed submergence; and each theory as to that cause, we shall find, is attended with special difficulties of its own. Take the first and most obvious account of it, that there was an actual subsidence of the land, or depression of the earth's crust to this extent, in this and neighbouring parts of the northern hemisphere. This was the theory adopted by Sir Charles Lyell and all the earlier writers on the subject. Proceeding chiefly upon the changes of level that have been observed in Scandinavia (though there is no proof that these go beyond very narrow limits), Sir Charles supposed a gradual subsidence at the rate of about $2\frac{1}{2}$ feet in a century, and that this might go on for nearly 100,000 years, till there was a submergence of over 2000 feet.* And, of course, this must have been followed by a re-emergence, in all probability equally gradual, and occupying a similarly long period of time. Passing over the improbability of such great oscillations of the earth's crust happening within comparatively recent times—while all through the Secondary formations and down to the later Tertiary deposits, the changes of level, as Sir Andrew Ramsay has shown, seem to have been comparatively insignificant†—passing also the improbability of such a great submergence (occupying this immense interval of time), leaving only such few and doubtful traces behind it; and merely noting that there is no proof of anything like such a submergence in other parts of the northern hemisphere,‡—let us take the much smaller submergence of between 500 and 600 feet, which is at present under our consideration. At the assumed rate of movement, a submergence of 550 feet would occupy 22,000 years, and the re-emergence an equal period, or 44,000 years in all—allowing the movement to have been constant and uninterrupted by any periods of repose. There seems to be ample time here—especially under the conditions supposed—for the accumulation and redistribution of considerable bodies of sediment, and, in short, for changes of no small extent in the aspect and physical geography of the country. Now, the theory is, that the re-elevation of the

* "Antiquity of Man," 3rd ed., chap. xiv.

† "Physical History of the Dee," *Quar. Jour. Geol. Soc.*, vol. xxxii.

‡ See paper already referred to, *Transactions*, vol. ix., part 1, p. 100.

land was followed by a return of Arctic conditions, and a second period of glaciation. And it is to be noted that this second glaciation seems to have been very much a repetition or duplicate of the first. It is true that several authors speak of it as "milder," "less intense," "on a smaller scale," than the first; but when, according to their own showing, the Firth of Clyde again became so choked with ice that a wide-spreading sheet of it found its only available outlet across the midland valley to the German Ocean; when the Irish Sea was again filled from side to side with ice from the Southern Uplands, and the Cumberland and Irish mountains; when the ice from the N.W. Highlands again extended across the Minch, and over the northern part of the Island of Lewis; and when the British and Scandinavian ice once more coalesced in the German Ocean*—it seems a waste of words to say that this second glaciation was appreciably less than the first.

But if it be hard to account for a subsidence or depression of the earth's crust at that particular time, and equally hard to account for its subsequent re-elevation, it seems to add very much to the difficulty that, after these great changes, occupying several tens or scores of thousands of years, the land should be supposed so nearly to resume its former aspect; that the temperature and all the climatal conditions,—the configuration of the country, the height of the mountains, and the direction and inclination of the valleys,—everything should be so nearly the same over again as to produce that highly complex result, a second glaciation, in all respects so closely resembling the first.

It is this consideration which has led many eminent geologists, both in Europe and in America, to deny a second distinct period of glaciation altogether—believing rather in the oneness of the Glacial epoch, with, of course, considerable oscillations of the ice, than in two or more distinct periods of glaciation, distinct and yet so nearly alike.†

(5) *Was the Submergence caused by a Rise in the Sea-level?*—According to the other way of accounting for the submergence, "the sea may rise upon the land, without any movement of the land itself." As Mr. Adhémar and Dr. Croll pointed out, a great

* "Great Ice Age," pp. 159, 562, 564.

† Falsan, "La Période Glaciare," p. 211, &c. Wright, "Ice Age in North America," pp. 500-1.

mass of ice in either hemisphere such as that which covered so many northern regions during the Glacial epoch would, of itself, by displacing to some extent the earth's centre of gravity, cause a rise of the sea in the hemisphere where the ice was in force. To what extent this would take place has been matter of considerable discussion and difference of opinion. But Dr. Croll's calculation was that the transference of the "ice-cap" (as it was then called) from the Antarctic to the Arctic regions might produce "a rise of the sea-level at the North Pole of 285 feet, and in the latitude of Edinburgh of 234 feet."* Dr. Croll thought there might be a considerable additional rise, resulting from the melted ice—assuming that the ice would melt on the one hemisphere more rapidly than it would form on the other—which seems to be doubtful, and may therefore be set aside. Here then, as Dr. Geikie remarks, we have "a *vera causa* of changes in the relative level of land and sea; and certainly it is remarkable that evidences of submergence should so often accompany marks of strong glaciation, as if the one were somehow dependent upon the other."† Let it be borne in mind, too, that this explains not only the submergence and its coincidence with the Glacial period, but what is equally important and equally difficult to explain on any other hypothesis, the re-emergence of the land when the ice-sheet diminished or passed away. So that it seems in all respects a more probable hypothesis than actual depressions and re-elevations of the earth's crust, happening, in some inexplicable way, at that particular time.

But if we adopt this as in all likelihood the cause of the submergence, then there must be some proportion between the cause and the effect. It is surely inconsistent to premise submergences of 1400 to 2000 feet, bringing in "actual subsidences of the land itself" to account for these, and leaving the more moderate ones to be accounted for by the ice-sheet alone.

Even as regards a submergence of between 500 and 600 feet in this country, it seems to be more than we are warranted in attributing to this cause. We have seen that Dr. Croll—who took larger data as to the mass of the ice than most physicists will allow—only estimated a rise of the sea from this cause, in the

* "Great Ice Age," p. 487.
† *Ib.*, p. 488.

latitude of Edinburgh, at 234 feet. In North America, where an area of about 4,000,000 square miles was covered by ice (more than double the area so covered in Europe) with an average thickness, at its maximum, of a half or two-thirds of a mile—yet with this enormous mass of ice the American geologists compute that portions of the North Atlantic, and of the Arctic sea, would only be lifted "perhaps, on an average, two or three hundred feet higher than now."* And a most interesting point is that the traces of submergence increase to a certain point northwards, as might be expected if due to this cause. Thus, near Boston, and north-east to Cape Ann, the coast seems to have been submerged to a slight depth, probably not exceeding 10 to 25 feet. Proceeding towards the north and north-west, the elevation of the marine beds lying on the glacial drift increases to about 225 feet in Maine, about 520 feet in the St. Lawrence valley at Montreal, and 440 feet at a distance of 130 miles W.S.W. of Montreal; but eastward, along the St. Lawrence, it decreases to 375 feet opposite the Saguenay, and does not exceed 250 feet in the basin of the Bay of Chaleurs. Along the east main coast of Hudson Bay, and on Hudson Strait, and in the region S.W. from James Bay, the submergence indicated is about 300 feet. On the other side of the continent, in British Columbia and Queen Charlotte Islands, the evidence points to a submergence of only between 200 and 300 feet, which corresponds with the smaller mass of the ice in that direction.†

If these are the figures for the North American continent, with its enormous ice-sheets during the Glacial period; and if in Scandinavia, where there is evidence that the ice attained to at least double the dimensions which it had in this country, the greatest submergence appears to have been barely 600 feet—(and some geologists doubt if it was so much)—it is difficult to believe that in this country, with a far smaller and more limited ice-sheet, the submergence (if due to this cause) should be equal to, or even exceed, the maximum shown by these other countries. Let us try a little simple calculation on this point.

* Warren Upham; see "Ice Age in North America," p. 579. "Among American geologists the belief in a great submergence of the land in late glacial and post-glacial times is passing away" ("Great Ice Age," p. 480).

† "Ice Age in North America," pp. 580-1, &c.

In America, as has been remarked, the phenomena are "writ large," they are presented with great clearness, and on an immense scale. Now, we find there that from latitude 40° to 51° N., or about 750 miles, the increase in submergence, or the rise in the sea level, seems to have been about 450 feet, or ·60 of a foot per mile ($7\frac{1}{5}$-inches).

Here, owing to our smaller area, our proximity to the sea, and the coalescing of ice-sheets from different quarters, the phenomena are perhaps less distinct and easily traceable.

But let us take two fixed points. Take England, south of the Thames and the Bristol Channel, to begin with. That district, according to Sir Charles Lyell, "seems to have remained land during the whole of the glacial period, at a time when the northern area was under water."* And Sir Andrew Ramsay concurs that there is no trace of glaciation—"no recognised boulder-beds in England anywhere in or south of the valley of the Thames."† Some geologists, however, more recently recognise a small submergence of that region—from 20 or 30 up to 50 to 60—at all events under 100 feet. If we say 100 feet in the latitude of the Thames valley, or $51\frac{1}{2}$° N., then our next fixed point will be on the coast of Norway, 65° N., where the submergence appears to have been about 600 feet. Assuming that there was a gradual uniform rise in the level of the sea from the south of England to the coast of Norway, which is the most probable hypothesis we can reason upon, and it is so far borne out by the facts of a similar kind in North America; we have here a rise of 500 feet in a distance of about 900 miles, which is equal to ·55 of a foot (or $6\frac{3}{5}$-inches) per mile. This is not far from the result we arrived at as regards America, a little less, as perhaps might be expected. Taking, then, our own country at this rate, 350 miles north of the Thames would give only $192\frac{1}{2}$ feet (or say 200) of a submergence; 400 miles, 220 feet, and even the extreme north of Scotland would only reach about 250 feet. Now this is very far short—much less than half—of what is required in the centre of Scotland for the supposed submergence under consideration.‡

* "Antiquity of Man," 3rd ed., p. 275.

† "Physical Geology and Geography of Great Britain," 3rd ed., p. 239.

‡ It is sufficient for our purpose if these results, from a fair use of the known facts, are at all approximately correct.

Thus, if we adopt the attraction of the ice as the probable cause of the submergence (or rise in the waters of the sea), we must reason from what we know, or can observe, of its effects in other parts of the world, and over the northern hemisphere generally; and all the facts we know regarding these seem quite opposed to a submergence of anything like 500 or 600 feet being possible in this country from this cause.

Tested by what is admitted regarding the "Second Glaciation."—We may note here, in passing, that the submergence which can be shown to have occurred during what is called the "second glaciation,"—which, from what has been admitted as to the extent of the ice and the effects it produced, must have been, as we have remarked, very much a repetition of the "first glaciation"—the submergence which occurred in the last cold period, and which, we may conclude, should be more clearly ascertainable than that which occurred in the first, seems to have been only about 100 or 125 feet.* This was the case, when the ice again attained such huge dimensions—when the whole country, except, perhaps, the highest peaks, lay buried under it, and great ice-sheets or systems of confluent glaciers extended all around it as before. Taking what is said of it by those who advocate it, it is hard to suggest any reason why the submergence which occurred during this so-called "second period of glaciation" should be only about one-fifth part of that which is claimed to have occurred during the first period, to which in all other respects it seems to have borne so striking a resemblance. I say it is hard to suggest any reason for this, if we proceed on the theory which we are arguing on at present, that the ice itself was the cause of the submergence.

Tested again by what is known of other Countries.—Referring again for a moment to other countries, we may note that, instead of the numerous oscillations and repeated submergences supposed by some geologists to have taken place in this country,† it seems there was in Norway just one partial submergence (which, as we have shown, there is every reason to believe, was greater than that

* Sir A. Geikie, "Text Book," p. 903. "Great Ice Age," pp. 254, 262.

† "How many submergences there were, we cannot at present, and perhaps never may be able to say."—*Op. cit.*, p. 188. We gather, however, that at least *three* or *four* distinct submergences are (or were) believed to be made out (pp. 184-5, &c.), which seems pretty well.

which took place in this country); and that this was not followed by another glaciation, but by the retreat of the ice and the re-elevation of the land.*

To the same effect, Professor Wright states that the only changes of level connected with the Ice Age in North America of which there is satisfactory evidence are the following:—(1) A pre-glacial elevation of a few hundred feet; (2) a depression varying in different localities, but as a rule increasing northward, from 150 up to 520 feet—the greater number of instances observed being between 300 and 400 feet; (3) a re-elevation towards the close of the period, of the regions that were thus submerged. These, he says, "seem to be all the changes of level which are absolutely required to explain the facts in hand." †

Is it not worth considering whether (with a narrower limit certainly as regards the submergence, corresponding with the smaller scale of the other phenomena) these would not also explain all the facts in this country? We may reasonably assume that the phenomena of the Glacial epoch were exceedingly uniform all over the northern hemisphere; and any scheme of interpretation which holds good over the greater part of the area is *ipso facto* more probable than a scheme which is good for one locality only—for Lewis, or Wales, or the east of England, or the North of Scotland—and differs entirely from that proposed to account for the corresponding facts in other localities.

Recapitulation.—For all these reasons, which we leave to have such weight as may appear fairly to belong to them, we find it impossible to believe that this clay at Chapelhall is a true shell-bed marking a former level of the sea.

Passing over the preliminary objections that might be raised on account of the imperfection of the evidence on which it rests, and the little that is really known of it; and taking all we do know, we have touched upon these points:—

(1) Its local and limited character, and the absence of all traces of it in a number of other localities, not only in the neighbourhood, but on both sides of the central valley where these might be expected, and in other parts of the country generally.

* *Op. cit.*, p. 410.

† "Ice Age in North America," pp. 414-5.

(2) The absence of marine organisms in the overlying Boulder-clay, which, if the sea had reached this limit, must have been largely formed of materials derived from the old sea-bed.

(3) If deposited during a period of great submergence and milder conditions, as had been alleged, it seems reasonable to expect, from all we know regarding the laws which regulate the distribution of the mollusca, that the marine organisms it contains would be of species indicating a more genial temperature than do those actually found at Chapelhall.

(4) If there was an actual depression and re-elevation of the land, occupying, according to all known data concerning such great crustal movements, scores of thousands of years, it seems highly improbable that the land should so nearly regain its former level just at the recurrence of another cold period, and so exactly resume its former condition, that an ice-sheet capable of depositing another great thickness of Boulder-clay composed of materials largely derived from the Western Highlands should again overspread the central valley of Scotland.

(5) If, on the other hand, the submergence was due to the mass and attraction of the ice itself, then we are met by the difficulties (*a*) that it is greatly in excess of the submergence traceable in other parts of the northern hemisphere, where the ice is known to have been in much greater force; (*b*) that the submergence traceable in these other parts seems not to have taken place at the same stage of the glacial epoch as this alleged great submergence in Scotland, *i.e.*, seems not to have been succeeded by a second glaciation; but to have taken place just prior to the final retreat of the ice and the "last elevation of the land;" and (*c*) that there is no degree of proportion discernible between this alleged submergence of 500 or 600 feet during the "first glaciation" and that which can be shown to have accompanied what is called the "second glaciation," which, however, from its extent and effects, seems to have been scarcely, if at all, inferior to the first.

Some of these reasons will doubtless appear more weighty than others; but taken altogether, we think they form tolerably strong ground against accepting this Chapelhall deposit as a true "shell-bed," and the submergence of "526 feet or more," which it has so frequently been taken to indicate, as proved.

III. *The Alternative Supposition—Transport by Land Ice.*—But if this patch of shelly clay was not laid down at this level by the sea—if there seem to be so many and such varied objections to concluding that it was so deposited—then the only alternative we can see is that it was somehow transported to its present position from a distance, and from a lower level; and the only agency known to be capable of doing this, and to have in many other instances actually done so, is land ice. I need hardly remind you of the numerous shelly tills to which I have alluded in an earlier part of this paper—such as those of Caithness, Lewis, the Endrick Valley, the south of Ayrshire, Arran, Wigtonshire, in our own country; the Isle of Man, Cromer, Holderness, Bridlington, in England; and in North America (not to multiply examples), near Boston and along the lower reaches of the St. Lawrence on the east coast, and at Vancouver on the west. We may say, in short, wherever the ice can be shown (from the direction of the striæ and the nature of the rocky fragments in the "drift") to have passed over a part of the sea-bed in its progress, there shells or fragments of shells have been found in the glacial deposits.*

If, however, it be objected that this is not, strictly speaking, a shelly till, but a patch or strip of shelly clay imbedded in the till, still we may reply such cases are not uncommon. Thus, in the Boulder-clay at Bridlington, as is well known, there occur patches of clay, or "argillaceous greensands, of small thickness, containing a considerable number of shells in a fair state of preservation." These patches, as Mr. Lamplugh has shown, are "not *in situ*, as at first supposed, but are masses torn off from the original bed, and re-deposited in the Boulder-clay." †

Such strips and patches of shelly sands and clays, it has been suggested, may have been in some instances frozen into a hard mass ere they were taken up by the ice-sheet, and so transported by it without much injury to the shells enclosed. ‡

* "The presence of such shells in the Boulder-clay of the lower reaches of the St. Lawrence is really no proof that the clay in question was deposited by the sea. The shells may quite well have been introduced into the ground moraine of the ice sheet which passed up the Gulf of St. Lawrence" ("Great Ice Age," p. 456).

† Prestwich, "Geology," vol. ii., p. 447. *Quar. Jour. Geol. Soc.*, vol. xxiv., p. 146.

‡ Peach and Horne "On the Glaciation of Caithness," *Proceedings, Roy. Phys. Soc. Edin.*, vol. vi.

A similar suggestion has been made with regard to strips and patches of clay containing plant remains and thin layers of peaty matter intercalated in the Boulder-clay of North America.*

Now, undoubtedly this locality, Chapelhall, lay in the very track of the ice, which (as shown by the striæ and by the pieces of granite, quartz, mica-schist, &c., in the Boulder-clay) originated among the Highland mountains to the north-west, and moved in a great sheet or *mer de glace* eastward across this part of the country to the German Ocean. The striations on the rocks everywhere in the neighbourhood, of which there are many clear and striking examples, as well as the stony contents of the Boulder-clay, demonstrate this. And the reason, of course, is that the choked and blocked condition of the Firth of Clyde, by ice from these mountainous regions, rendered egress for the whole of it in that direction impossible. Now, if in Loch Lomond and Loch Long, for example, there is evidence that the ice was not less than about 3000 feet thick, here, around Airdrie, it may still have been over 2000 feet in thickness. We may take for granted, as sufficiently obvious, that the ice must have moved across part of the sea-bed on its way hither. And it is quite credible, for we know it has done so in a multitude of similar cases, that it should take up and carry forward with it shells and pieces of clay charged with shells from that sea-bed, and deposit them elsewhere in its progress.

As a subsidiary point, it may be worth noting that the locality in which these shells were found is not only in the main track of the ice-sheet across the country, but immediately in front of the highest ground or watershed of the district, and where the ice was most likely (as some one has remarked in a similar case) to make a "long pause" either in advancing or retreating. It is immediately in front of one of those great masses of basalt which in this district rise through the Coal Measures and partly overflow them, and which, from their greater hardness, have more effectually resisted the denuding agencies. Accordingly, the level of the country rises rapidly here; while it is only 300 feet at Coatbridge, the 500 feet line runs close to Chapelhall (it is 526, as has been said, on the surface at the well); and a little farther east it rises to 928 feet at Torrance and 959 at the Kirk of Shotts. It seems to be just the sort of locality where anything being carried forward

* "Ice Age in North America," p. 287.

by the ice would be most likely to be deposited; and the conspicuous ridges of Boulder-clay all around, to which I have referred, corroborate this statement. It seems to be where the ice meets with some decided obstruction, that such things are most apt to be deposited by it—of which illustrations might be adduced from Caithness and elsewhere.* In short, this case at Chapelhall seems to present on a smaller scale what happened at Moel Tryfaen, and also on the Dublin and Wicklow hills, where such deposits of transported materials were left on prominent outstanding obstructions in the path of the ice.†

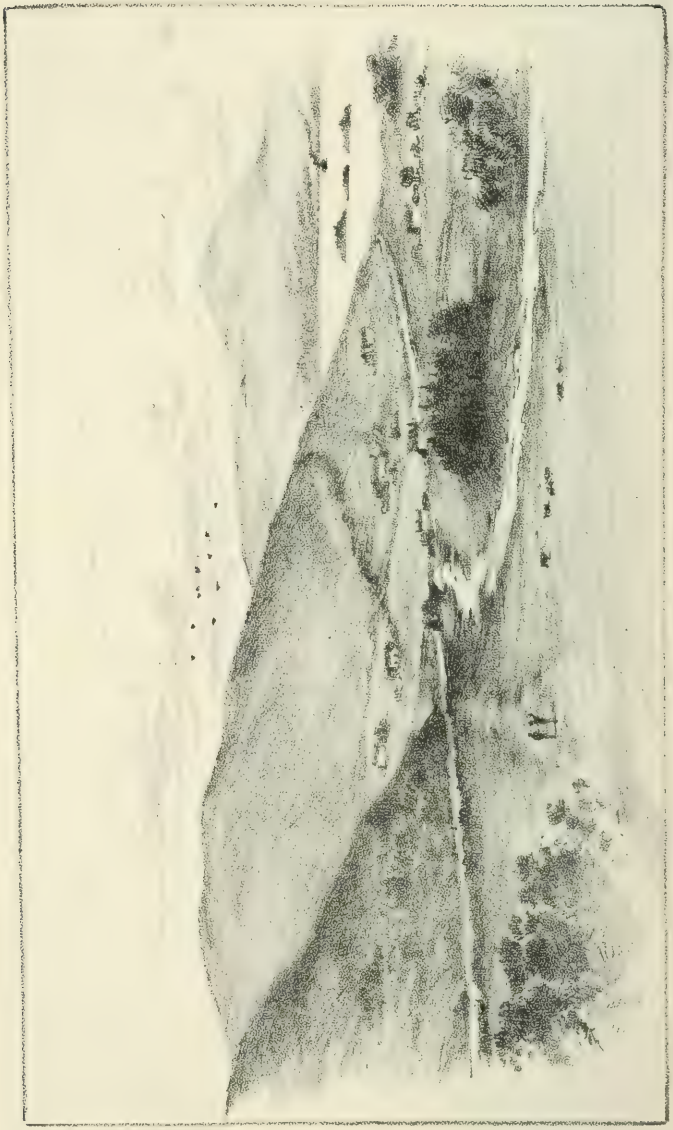
I need not pursue the subject further at present. The other "high-level shell-beds" in Scotland—those of Aberdeenshire and Nairnshire—I purpose considering on another occasion. Meantime, I am confirmed in the view I have taken of this subject, by finding that Sir Archibald Geikie, in the last edition of his "Text-Book," expresses himself with great caution and reserve regarding these "high-level shelly deposits." He says, "they are probably not conclusive proofs of submergence," for "they may have been picked up from the sea-floor by moving ice," as in the various instances to which we have already referred. He dismisses the shells at Moel Tryfaen as "probably not really in place;" and with regard to this instance at Chapelhall, he admits that "the layer containing them may have been transported by the ice-sheet,"—which is virtually giving up the case for submergence.‡

I venture to think that the more the matter is considered, and the difficulties against any other hypothesis fairly weighed, the more will this explanation commend itself to the minds of geologists. I accordingly submit that this instance of Chapelhall ought no longer to be cited as a proof of submergence.

* See Peach and Horne, *Proc. Roy. Phys. Soc. Edin.*, vol. vi.

† We may also notice in passing the colour of the clay—red, or, as Mr. Russell described it to Sir A. Geikie, "a fine reddish brick-clay." The clay proper to the Carboniferous rocks is, we need hardly say, of a much darker tint, "bluish-black, dull blue, or leaden." So that from this description, the shelly clay would certainly appear to be of an origin foreign to the district.

‡ *Op. cit.*, pp. 897-902, and "Scenery of Scotland," 2nd ed., p. 366.



GLEN FRUIN—DISTANT VIEW OF MORAINE.

CARTER & PRATT, LITH.

No. XXVIII.—On a Glacial Mound in Glen Fruin, Dumbartonshire. By Dugald Bell, F.G.S. With Two Plates [Nos. XII. and XIII.]

[Read 28th May, 1891.]

Glen Fruin* is a quiet secluded glen, about 6 miles in length, extending in a north-westerly direction between Loch Lomond and the Gareloch, and opening off the neck of land which divides these lochs at between 200 and 300 feet above the sea. On the south-east it slopes towards Loch Lomond, of which the Fruin water is one of the principal affluents. On the west it is bounded by a range of hills 1000 to 1200 feet in height, which at the upper extremity, towards Garelochhead, subside into a col or pass of 600 or 700 feet. The upper part of the glen is composed of the mica and clay slates common to the Western Highlands. The lower part is formed of beds of the Calciferous Sandstone series, which have apparently been faulted down between the adjacent Old Red Sandstone and the older Silurian rocks.

The huge boulder of mica-schist, resting on the sandstone, at Callendoun, near the mouth of the glen, about 200 feet above the sea (and measuring 28 × 18 × 10 feet), was brought under the notice of the Boulder Committee of the Royal Society of Edinburgh by Mr. R. L. Jack, when engaged on the Geological Survey of the district, and was afterwards visited by the Convener of the Committee, the late Dr. Milne-Home, and figured and described by him in one of the Committee's annual Reports. By some mistake, as we formerly pointed out,† either Mr. Jack, or the Convener in copying his note, *reversed* the position of the boulder, stating that it lies "with sharp end to west and thick end to east"‡—the fact being that its sharp end is distinctly to E. (or S.E.), and its thick end to W. (or N.W.). Dr. Milne-Home considered it more particularly with reference to his favourite theory of floating ice or icebergs; his only doubt being whether it came down Loch Lomond and turned aside into Glen Fruin, or over from the west, from the neighbourhood of Loch Long and Loch Goil.§ He

* "Glen of Sorrow"—scene of a sanguinary conflict between the Colquhouns and Macgregors in 1603 (see Introduction to "Rob Roy.")

† *Transactions*, vol. viii., part 2, p. 256.

‡ "Second Boulder Report," p. 68.

§ "Second Boulder Report," p. 20.

inclined to the latter conclusion, because this seemed to him to be the direction in which the "bergs" generally came—at least in the midland districts of Scotland—all difficulties being got over by supposing a sufficiently great submergence. It is to be noted that there are many other boulders in the neighbourhood, some of considerable size, up to heights of 500 or 600 and even 1000 feet.*

We need not here enlarge on the various objections to the iceberg hypothesis—as (1) the absence of any separate and distinct proof of such a submergence as the theory presupposes; (2) the difficulty of seeing where, in the event of such a submergence, the large icebergs required could be formed—besides the probability that there would then be, in this country, or in what was left of it, little or no ice at all; (3) by what possible main currents of the ocean (which alone could move them) these icebergs could be brought to many of the localities in which the boulders occur—land-locked bays and side-glens being necessarily quite out of their track; or (4) how they could pick up and carry forward specimens of the various kinds of rock submerged beneath them on their way, and lay down an accumulation of débris derived from far and near, but mainly from the immediate neighbourhood of where it is deposited.† For these reasons, and others that might be added, we reject the iceberg hypothesis, and conclude that such boulders owe their transport to a great sheet of *land-ice* which once filled the glen from side to side, proceeding from the Argyleshire mountains on the north-west, and overflowing the rock or col at the head of the glen, as also that at the head of the Gareloch, between it and Loch Long.‡

This view is strongly corroborated by the phenomenon which we have now to describe, viz., a remarkable mound or ridge of detritus extending for a considerable distance on the hillside to the east of the glen, in a direction transverse to the glen itself; and which, there can be little doubt, is a true terminal moraine left by the ice at this point during its retreat. We first observed it rather more than a year ago, when visiting the glen with a

* *Transactions*, vol. vii., part 1, p. 172, and vol. viii., part 2, p. 255.

† *Ib.*, vol. viii., p. 245, &c.

‡ As noticed many years ago by Mr. C. Maclaren, *Edin. New Phil. Jour.*, vol. xi.

friend who wished to see the "big boulder" at Callendoun. Having satisfied our friend's curiosity in this respect, we proceeded about a mile farther by the road up the eastern side of the glen, and turned down the by-road towards Inverlaurin farm, in order to cross the Fruin by the bridge there, and so regain the Helensburgh road. In going down this by-way it struck us as being raised above the general level of the moor, and formed on the top of a stony or gravelly mound, which we thought was very unlikely to have been gathered for the sake of forming a farm road. It seemed more likely that a natural mound at this point had been taken advantage of for the purpose. This was immediately confirmed by the ridge or mound becoming too high and hummocky for the road, which then ran alongside of it, but still getting the benefit of the stony material. Having called the attention of our friend to what we had thus observed, we turned back a little way to ascertain if the line of mounds could be traced farther than the road by which we had come; and there certainly we did see it extending for some distance very distinctly up the hill on the opposite side. We had not time then to examine it more particularly; but a few weeks later we had an opportunity of following it more fully, and noting the particulars which it is the object of this paper to communicate.

Immediately to the north-east of the farm house of Inverlaurin, just behind the shepherd's cottage, the line of mounds is exceedingly well defined. From this point (about 300 feet above the sea) it extends in a north-east direction up to the public road (at 400 feet) where a schistose boulder of some size leans against it, as if specially to mark its position.* Across the road we see it rising very conspicuously in the same general direction, as a succession of green mounds on the hillside, as far as the boundary dike of the moor attached to the farm. Beyond this dike (450 feet) we follow it, still to the N.E., for more than a mile, to where the shoulder of the hill begins to curve round towards Glen Finlas. It continues wonderfully distinct all along its course—one part, to the north of the dike, rising from the moor almost as evenly as a railway embankment. Across the face of Shantron hill it "tails out" in a long upward curve, to about 700 feet, which may be distinguished from a considerable distance.

* Plate XIII., fig. 1.

Of course it is not quite straight, but winds in and out, in a succession of little bays and promontories; nor is it quite level, but has higher and lower parts, showing in some places like a succession of little hills or hummocks. Its general direction, however, is, as we have stated, N.E. and S.W. The glen runs N.W. to S.E., so that the ridge is plainly transverse to the glen. Its height above the surface of the moor varies from a few feet to 10 or 12, and in some parts 20 to 25 feet; and its average breadth may be from 30 to 40 feet. The "burns" coursing down the hillside have cut into it, and even through it, in some places, clearly revealing its structure.* It is composed of stones, sand, and gravel promiscuously thrown together, with but faint traces here and there of anything like stratification. In short, it is typical moraine matter—as like as possible to the moraines we have seen near existing glaciers in Switzerland. The stones are chiefly mica and clay slates, with fragments of quartz and some felstones, and a considerable proportion of sandstones from the immediate neighbourhood—these last, as far as we observed, being more abundant near the middle of the glen. These stones are mostly angular or sub-angular, but a few are of a more rounded form. Scattered about at the base of the mound, and here and there on its sides and top, are larger boulders of various kinds, chiefly of the harder schists and quartzose conglomerates, which have been brought from a greater distance. We also found one or two well-rounded pieces of grey granite, with large crystals of felspar, similar to boulders found elsewhere on the west coast, on the shores of the Gareloch and Holy Loch, and on the opposite side of the Firth, near Gourock. The origin of those boulders was undoubtedly a tract of porphyritic granite extending around Meall Breac on the eastern side of the upper part of Glen Fyne. They occur in great numbers near St. Catherines on the same side of Loch Fyne.

On examining the stones imbedded in the mound, we find many of them distinctly striated, chiefly along the line of their longer axis. This is generally admitted to be a sure indication of glacial action. [Specimens shown.]

Altogether, there can be little doubt this is a "terminal moraine" of the great ice-sheet which once occupied the glen; and, we may

* Plate XIII., fig. 2.

RIDGE OF MORAINE.

SECTION OF MORAINE.

CARTER & PRATT, LITH.

add, it is one of the most notable and characteristic which we have seen in the West of Scotland.*

About half-a-mile farther down the glen, on the farm of Highfield, there are traces of lower and more gently sloping mounds, now under cultivation.

A number of detached mounds of considerable size occur at still lower levels, beyond the opening of the glen towards Loch Lomond. There are two near Banachra, one of them, the largest in the neighbourhood, called Dunfin (the hill of Fingal) rising about 100 feet above the surrounding ground, and bearing traces of a hill-fort on its summit. There is another farther down, near the farm of Nether Ross. These are, doubtless, relics of older moraines; and the locality, where the Loch Lomond and Glen Fruin ice must have met, seems a likely one for such accumulations.

Farther up the glen, about the middle and towards the head of it, though there are many boulders and hummocks of débris scattered about, we observed nothing like the distinct and continuous moraine which has been described. The upper part of the glen, we may note, is occupied by a long stretch of flat meadow land, which seems to be the bed of an ancient lake, "ponded back" no doubt by heaps of moraine matter, which the stream has long since cut through and washed away.

Returning to the farm house of Inverlaurin, the ground to the west of it slopes rapidly down to the channel of the Fruin, the waters of which have evidently from time to time swept a considerable breadth of the valley. On the other, or western side of the river, there are some well-marked ridges of sand and gravel extending across the moor in a direction south-west by south, which may very probably be a continuation of the same moraine.

Meantime this interesting relic of the "Ice Age" suggests some important considerations and inferences:—

1. We may take for granted, to begin with, that such a distinct and continuous line of mounds could only be formed by a sheet of land-ice.

* We learn that when the officers of the Survey were in the district they examined a gravel-pit which had been opened near Inverlaurin, and described it as "Earthy gravel, a few of the stones striated"; adding with a query ("?"), "moraine rubbish." They thus seem to have had a glimpse, at least, of the moraine; but, so far as we are aware, the long continuous line of it, which we have described, was not observed.

2. It seems equally evident that there has been no submergence to this point *since* the mound was deposited. Its rough, undressed, unstratified condition—its very existence as a distinct mound—proves this. Had there been a submergence of as much as 500 feet since it was deposited, such a loose earthwork would soon have been demolished and effaced by the currents sweeping across this neck of land between Loch Lomond and the Clyde.

3. For the same reason we may conclude there could be no submergence to that extent *while* the mound was being deposited. Some geologists hold that the ice-sheet reached the sea as the land rose (assuming a submergence), and laid down heaps of detritus along the sea-margin. In that case such accumulations would undoubtedly have borne distinct marks of assortment and stratification, especially in localities where strong currents must have been in operation.

4. Further, in connection with such mounds, there is a striking absence of any proof of a "great submergence" *prior* to their formation. The advocates of such a submergence hold that there was a first or general glaciation, then a deep submergence, then a partial or local glaciation, by which all distinct traces of the submergence were removed. But a little reflection will show (*a*) that it is very improbable any subsequent local glaciation could remove all traces of the sea's presence at high levels, supposing it had been there;* and (*b*) even supposing such traces had been entirely removed by ice from every glen such as this, it seems reasonable to expect that they should at least be discoverable, more or less, in the heaps of débris which the ice has so frequently left near the mouths of these glens. All over the country there are innumerable glacial mounds and heaps—the "sweepings" of glens which, in the case of the alleged submergence, must have been sheltered inlets of the sea, favourable to a great variety of forms of marine life. Can any good reason be assigned why these heaps, as well as the Boulder-clay of the country generally, should not abound in fragments of marine fossils, if there had been such a submergence, instead of being, as they are on the whole, quite destitute of organic remains?

This argument is not founded on a supposition, but on a fact. Wherever the ice can be shown (by the striæ on the rocks, the

* *Transactions*, vol. ix., part 1, p. 109.

stones in the "drift," &c.) to have passed over what is still a sea-bed, or must have been so during a very moderate submergence, there also numerous fragments of sea-shells are found in the drift or Boulder-clay; as in the instances of Caithness, Arran, Drymen, South Ayrshire, Holderness, Cromer, Lancashire, &c.

The argument is strengthened also by a consideration of the long periods of time which, it has been estimated, the gradual subsidence of the land to the extent or degree supposed, and its equally gradual re-emergence, must have occupied.* All traces of such a prolonged occupation by the sea would not be easily removed or obliterated.

The advocates of a "great submergence" have, therefore, these two facts to account for—(1) the absence of all clear proofs of such submergence *in situ* at the high levels to which it is supposed the sea attained; and (2) the absence of all evidence of it in the débris *derived from* these high levels.

5. The prominence and continuity of this line of moraine shows that the ice must have remained at or near this point for a considerable time—this must have been, for a long period, the average limit of the lower edge of the ice-sheet. It must evidently have taken a long time to accumulate such heaps of débris from the waste of the surrounding hills. The ice had doubtless many oscillations —periods of retreat to some extent, during which some inner or upper lines of moraine were formed; succeeded by a fresh advance when these were again borne forward and incorporated with an older and lower line. But this line, which remains so wonderfully distinct, may be taken as representing its average limit during a long period, and as, therefore, indicating a prolonged continuance of tolerably uniform climatic conditions. The question arises, can we trace similar well-marked lines of moraine at about the same level in other glens? If so, they may furnish additional proofs of a long interval of approximate uniformity in the climate. They may also confirm, in some measure, our observations regarding the alleged submergence.

Now, we have been struck by the fact that, in other parts of the country where similar terminal moraines have been found, they seem frequently to appear in a distinct and noticeable form about this same level of from 300 to 400 feet. Thus Mr. Jamieson

* "Antiquity of Man," p. 485.

of Ellon, who has contributed so many valuable observations on Glacial geology, states that he observed "a remarkably fine series of moraines in the valley of the Feugh, which is a tributary of the Dee. These moraines occur at levels of 300 and 400 feet." He adds, "they appear to be perfectly undisturbed, and, so far as I can judge, have never been touched by the sea since they were formed."—Another moraine farther up the valley "comes down below the level of 300 feet."—Two miles farther up, there is another "fine moraine at a level of about 300 feet." Its great size "marks a very long pause of the glacier here."—And still farther up there is "a fine little moraine at an altitude of about 440 feet, forming a characteristic crescent-shaped ridge," evidently "just as the glacier left it."—On the south side of the Grampians also, Mr. Jamieson states, he found similar terminal moraines at levels implying similar glacial conditions. "In Kincardineshire," he says, "I observed one at Drumlithie, near the railway station there, at an altitude of 280 or 300 feet above the sea, formed apparently by the glacier of the Bervie, a small stream which takes its rise among hills of from 1500 to 1700 feet in height. When this moraine was formed the glacier was seven or eight miles long." Mr. Jamieson continues, it "appears to me to be a terminal moraine. It consists of a long narrow mound, or series of mounds, from 20 to 30 feet high, with sides sloping at angles of 20° to 30°, curving in a crescent or horse-shoe form, with the convexity seawards. So far as I could make out, it is composed of coarse gravelly débris, irregularly piled together. . . The action of the sea would rather level such a mound than make it."*

This is exactly similar to the moraine we have been describing; and the Bervie glacier seems to have been almost a duplicate of that in Glen Fruin.†

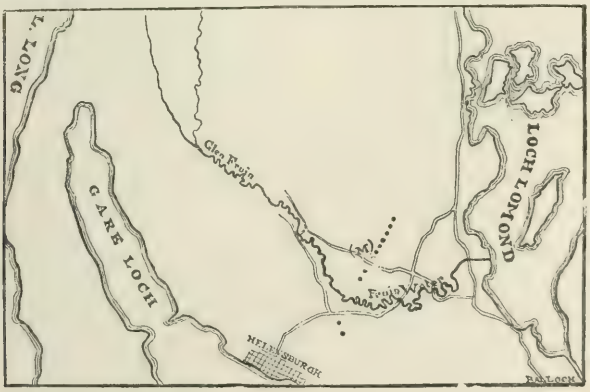
Now, in all these cases, as Mr. Jamieson has pointed out, "the glacier, and not the sea, was the last occupant of the surface."

* "On the Last Stages of the Glacial Period in North Britain," *Quar. Jour. Geol. Soc.*, 1874, pp. 325, 326.

† We do not mean to represent that about 300 feet is the lowest point at which such moraines appear in a distinct and undisturbed form. On the contrary, they come much nearer the existing sea-level in many localities where the mountains approach the coast. But many of the average-sized glaciers would certainly stop at some distance from the sea; and, as shown, many of them seem to have halted long about the present 300 feet line.

The only point on which we differ from this esteemed observer is that he favours a previous "great submergence," of which, as we have said, we think the proofs are lacking.

6. Another point of some interest is the comparative absence of any such lines of moraine in the upper parts of the glen—as if the ice-sheet, which had remained long about this level, when it did begin to give way had not made a similar lengthened pause at any subsequent stage. From the comparative absence of such well-marked terminal moraines in the middle portion of many glens and valleys, it has been inferred that the ice must have given way with considerable rapidity at last, not remaining long enough at any given point to form any very distinct accumulation of débris. Thus, Mr. Jamieson has observed, there are long intervals between such moraines in the valley of the Dee, as if the ice there had retreated by large stages. "Ten miles up the valley we find indications of a halt" at the Loch of Drum. "At Aboyne (20 miles farther up) there are indications of another halt." But "the longest and most decided pause" has been near Ballater, about 40 miles from Aberdeen. Other moraines of later origin are to be found in the upper branches of the Dee, at from 1600 to 2000 feet. These facts lead to the conclusion that at times "the ice seems to have receded rapidly over a wide area without leaving any marginal deposits." This corresponds also with what may be observed in Glen Fruin, and doubtless indicates the decided climatic changes which ushered in the close of the Glacial epoch.



Sketch Map showing position of Mound (M).

SUPPLEMENTARY NOTE.

A note may be added on a suggestion which has been made by one or two members of the Society who have visited the moraine, viz., that it may possibly be the *lateral* moraine of a "branch" of the Loch Lomond glacier which here extended across the neck of land between Loch Lomond and the Clyde. To this there seem several formidable objections:—

1. Glaciers do not turn aside, or send out "branches," unless some obstruction compels them. Their tendency and practice is to move straight on, disregarding "openings" that do not lie in their direct path. They are unlike rivers in this respect, which spread out and turn aside on every opportunity. Hence glaciers often pass straight across lateral valleys, blocking them up, and forming lakes in them.

Now, what could make the Loch Lomond-glacier turn aside, or send out a "branch" in this direction?—just where the loch opens out to its widest, and with the Vale of Leven on the one hand, and Strathendrick and Strathblane on the other opening out before it.

2. If its way in that direction was open, it is equally certain that its way in this direction was barred. There was "no thoroughfare" for it this way. There is every indication that the Firth of Clyde at this part was completely blocked by ice proceeding from the mountainous region around Loch Goil and Loch Long, which was in such mass that it passed straight across what is now the opening of the Firth, and over the hills behind Port-Glasgow and Kilmalcolm. It also pressed easterly into the Gareloch, into Glen Fruin, and along the hills near Helensburgh. It seems quite clear that the ice which came down Glen Fruin, instead of turning westward towards Helensburgh, moved still eastward towards Loch Lomond, and at its maximum coalesced with the ice there.

3. This is confirmed by the striations which were visible some years ago on a sandstone quarry near Crosskeys, to which I have formerly referred. ("Among the Rocks round Glasgow," p. 162.)

4. The conclusion that this is a terminal moraine of the Glen Fruin glacier seems to accord better with all the features of the moraine itself—its general form and direction, its greater prominence near the centre of the glen, and the materials of which it is composed.

Looking at all the features of the place, it seems quite probable that the lower part of Loch-lomond might be almost, or entirely, free of ice long before the Fruin glacier disappeared from the glen.

A few other localities in the West of Scotland, where well-marked moraines may be seen are—near Balmaha, Ardlui (head of Lochlomond), Glenfalloch, Balquhidder, Glen Dochart, Aberfoyle, Lochgoil near Carrick Castle, Glen Messan, and Bridge of Weir. D. B.

No. XXIX.—The Ardrossan Shell-mound, with an Account of its Excavation. By John Smith. With a Plate [No. XI.]

[Read 9th March, 1891.]

In various parts of the world, notably along the Baltic coasts of the Danish islands, the eastern coasts of America, and near the shores of many of the Western Islands of Scotland, are found mounds of varied size composed for the most part of shells of the edible species of molluscs, such as limpets, periwinkles, cockles, and oysters. Interspersed with these are found the bones of many mammals and birds; also weapons and tools of flint, dolerite, horn, bone, and wood, including celts, scrapers, chisels, arrow-heads, sling-stones, anchor stones, and other articles which had been made and used by a prehistoric race of men.

In Denmark these mounds, which are called kjökken mödding, reach the dimensions of from 100 to 1000 feet in length and from 3 to 10 feet high. They have yielded many implements made of similar materials to those above mentioned; but no articles manufactured from any kind of *metal* have ever been found in them. From this circumstance these shell-mounds have been referred by archæologists to the neolithic division of the Stone age. The shell-mounds of the American coasts have a great resemblance to the Danish ones, also containing implements, bones, &c., and are supposed to have been formed by the aboriginal inhabitants previous to the occupation of America by the "white man."

The Scottish shell-mounds are, generally speaking, smaller than any of the others, but, like them, contain the bones of animals, and stone, horn and bone weapons and implements. In the Western Islands of Scotland the shell-mounds often contain a kind of stone implement still used by the islanders, and called "Orst Barnach," or limpet-hammer. In some mounds on the Island of Oronsay, which I examined in company with Mr. Galloway, these limpet-hammers were rather common. They were simply, in this case, selected pieces of clay-slate suitable for holding in the hand, which by constant use in shoving the limpets from the rocks, had assumed, at the ends, somewhat the appearance of a blunted "jumper." Amongst the implements there was another type, which puzzled us to understand what it had been used for. Only about the size of a finger (some examples not half so big) it was

sharpened in the manner of a polished celt, although the body of the implement had not been worked or polished but had simply been selected for its natural shape. The great peculiarity about these Oronsay shell-mounds is the distance they are from the present shore-line, which strongly suggests the idea that there has been a considerable rise of the land since their formation. As will be seen further on, the evidence furnished by the Ardrossan shell-mound is in the same direction, almost demonstrating, in fact, that there has been a rise of a good many feet since the first occupation of this part of the Ayrshire coast by the shell-mound builders. It is this part of the subject which gives the mound its peculiar geological interest.

The Ardrossan shell-mound is situated on the south-west side of the Cannon Hill, close to the Ardrossan station of the Glasgow and South-Western Railway, the whole length of its north-east side lying against and under the rocky side of the hill. It measures 102 feet in length, with an average breadth of about 16 feet, but it has been much broader before the station was formed, a considerable portion having been removed, and a complete longitudinal section exposed, by the railway works. Its length, which appears to have been at one time somewhat greater, is mostly overhung a few feet by the rock-face; and facing the south-west, as it does, the place must have formed a snug shelter for its human occupants. Its formation appears to have been a slow process, and, as will be presently seen, it has been deserted at intervals for considerable periods of time. By their practice of always throwing the castaway shells and bones on the floor, the inhabitants seem to have gradually shut themselves out of the best part of the shelter, which had become more or less filled by the débris of their repasts and feasts. For its whole length the mound rests on a surface sloping upwards, as will be seen from the longitudinal section given in Plate XI. Having had the contents turned bodily over, with the exception of a few feet at the upper end where it would have been risky to do so, I found that underneath the whole of it, and resting on the rock, there was a bed of Raised-beach sand and gravel, about a foot in thickness, and containing rolled shells.

That this place had been occupied by man shortly after the waves left it was clearly evident, as there had only been time

sufficient for a layer of earth little more than *half-an-inch* in thickness to form on the top of the gravel, nor had there been time for any talus of fragments from the rock-face to gather upon the gravel before the inhabitants began to throw down the shells and other debris upon it. In fact the talus of rock-splinters was formed *on the top of the mound*, as will be seen from the cross-sections (Plate XI., figs. 1 to 5), demonstrating at once its antiquity, and affording some guidance to the time of its commencement. Another point in favour of its antiquity is the fact that many specimens of a spiral mollusc, *Trochus lineatus*, were got in the mound, and must have been common on the then-existing shore. This mollusc is now extinct in the Clyde, and in the West of Scotland, and has only been found in the Clyde district once before as a *fossil*, Mr. David Robertson having got it in the Raised-beach strata of Millport, near the College.

Cockles appear to have been very rare in the sands of the neighbourhood, as only two valves were obtained from the mound, and of spout-fish only one small valve, while the "hugger-fish," *Tapes decussatus*, the "horse mussel," *Mytilus modiolus*, and the "clabbydoo," *Mya* of various species, were totally unrepresented. The horse mussel is rare as a fossil, and diminutive in size in the Raised-beach beds of Ayrshire, as is also the hugger-fish, and the clabbydoo is apparently absent from them. The species of the latter shell-fish most frequent in this district at the present day is *Mya arenaria*. In the lower estuary of the Garnock it was very abundant, in muddy and gravelly sand, twenty years ago. To discover their whereabouts one had nothing to do when the tide was out but to stamp on the wet sand, when numbers of small squirts of water would rise, at once revealing the exact position of their holes. But this species has been almost exterminated in this locality by the people carrying them off for food. A boy whom I met with a cargo one day spoke highly in their praise, declaring that they were "better than beef." The other species, *Mya truncata*, which was abundant during the Glacial period, is not found in the Raised-beaches of this locality, but appears at the present time, though very rarely, in this district of the Clyde.

The two principal shell-fish which had been used for food by the shell-mound builders were the periwinkle and the limpet, occasional

specimens, especially of the latter, being large and ponderous. A few specimens of the small shore variety of the whelk, which is still common under stones on the north Ardrossan shore, were got in the mound; but of the larger variety, which lives on a sandy bottom and is frequently thrown ashore during storms, not a single specimen was obtained; mussels were not very common, and oysters were scarce. The edible crab was represented by a single claw, and the lobster was totally absent. Of fish remains only a few bones of the cod and conger eel were obtained, so that these ancient people evidently did not belong to an eminently ichthyophagous tribe. On the contrary, they had been great flesh-eaters, as is evidenced by the remains of the land animals upon which they fed. Although, like their contemporaries in the Western Islands, they lived largely on limpets, not a single "Orst Barnach" was found in the Ardrossan mound. There is evidence that they ventured out to sea, probably in small canoes, for a stone anchor with a groove cut round it, for the purpose of fastening it with some kind of rope, was got.

I commenced the exploration of the mound at the lower and wider end, and worked up hill, keeping, as far as possible, the full breadth and depth of the face before me, and testing the depth and quality of the underlying Raised-beach gravel now and then. Amongst the first articles turned up were a few fragments of very rude hand-made pottery of exceedingly coarse quality and badly burned. This kind of pottery is very rare on the Ayrshire sands, the reason evidently being that such imperfectly put-together material could not withstand the disintegrating influences of the weather for any length of time. The pieces got in the mound probably owe their preservation to their having been well covered up from exposure.

Having got a proper working face formed, I measured the first section as follows, in descending order:—

1. Talus, on top of mound and lying against rock face.
2. Shell bed, - - - - - - 6 to 18 inches.
3. Reddish soil, - - - - - ½ ,,
4. Raised-beach bed, - - - - - 4 to 12 ,,

No. 2 bed was for the greater part composed of *Littorina littorea* and *Patella vulgata*, with a few *Buccinum undatum* (small variety), *Ostrea edulis*, *Mytilus edulis*, *Littorina obtusata*, and *Nassa reticulata*. The last two are not now considered edible

species, and possibly may have been carried up by the children to play with, or perhaps gathered with the others and thrown out.

A great many jaws with teeth, and bones were obtained, all the latter which had contained marrow having been split open. Under the ledge of rock at point *a* [see Plate XI., section 1], and imbedded in the mass of shells, was a human upper jaw without teeth, which had evidently been knocked out with a stone, splinters of the jaw having been broken off in the process. On finding this grim relic my first impression was that the people who lived here had been cannibals, the jaw having evidently been thrown in the most matter-of-fact way on the general shell-heap, while probably the teeth had been kept to make a necklace or other ornament. Further evidence, however, obtained during the exploration showed that, although the mound-men had feasted, probably during "hard times," on their own species, they were not habitual cannibals, for the whole human remains obtained seemed to show that not more than two human beings had been devoured.

My next cut was up to a boss of rock 10 feet long by 5 feet wide, which I have named the *Cannibal's Seat*. Working in between this boss and the overhanging rock-face the section was found to be as follows:—

	Feet.	Inches.
1. Talus of rock débris.		
2. Rock débris, mixed mostly with periwinkles,	1	6
3. Black layer, - - - - - - - - -	0	1
4. Shell and bone bed (with a bone implement),	1	6
5. Earth, - - - - - - - - - -	0	0½
6. Raised-beach gravel, with rolled shells, - -	1	3

Besides the shells already mentioned a valve of *Mactra subtruncata* was got in this cut. In the bottom layer of shells, but not touching the Raised-beach bed, occurred a well-rounded boulder about 2 cwts. in weight, having probably been used as a seat. The black layer (3) had evidently resulted from this narrow pass between the boss and the ledge having been used by the occupants as a pathway to the higher reaches of the mound. Next the boss in this bed the shells were mostly periwinkles, whilst under the ledge they were principally limpets. Had the limpets been thrown under the ledge to keep their sharp cutting edges away from the bare feet of the occupants? Under the ledge of rock, both above and below this spot, the shells and bones were cemented

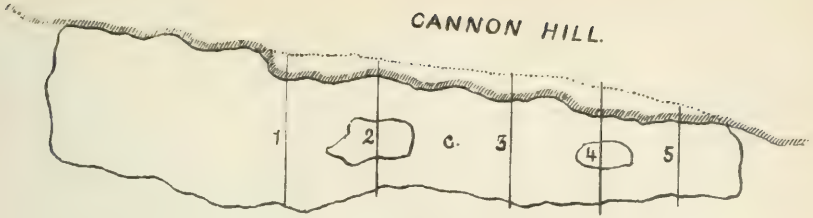
together into a solid mass by stalagmite, the lime having been derived partly from the overhanging rock and partly from the decomposition of the shells by rain-water. Part of a human lower jaw was got in the mass of shells (at *b*, Plate XI., section 2), and about a foot above the Raised-beach bed; it had three well-preserved teeth. Near the top of the same bed a well-made diamond-pointed bone chisel, a rude implement made of a human bone, and several human vertebræ, were obtained. Having worked up round the "Cannibal's Seat" an open face was again made, and here (at *c*, Plate XI., plan), the remains of a fire were come across. It had been kindled on the Raised-beach some 30 feet above present tide-mark, and showed that from the first occupation these people had been acquainted with the use of fire. Evidently, however, they had not roasted any of their meat, as none of the bones showed the touch of fire. In this cut the sandstone anchor already referred to was got. It measured 7 inches in length by $6\frac{1}{2}$ inches at one end and 8 at the other; the groove round it having apparently been chiselled out with a stone. The first valve of the edible cockle, *Cardium edule*, was obtained here, as also three specimens of the dog winkle, *Purpura lapilis*.

The section (Plate XI., no. 3), at this part of the mound measured—

	Feet.	Inches.
1. Talus.		
2. Shell and bone layer,	1	8
3. Shell-meal,	0	2
4. Shell and bone layer,	1	8
5. Earth,	0	$0\frac{1}{2}$
6. Raised-beach bed,	1	0

The layer in this section of what I have called shell-meal (3) was composed of thoroughly decomposed shells and bones, and showed that the mound, or at least this part of it, had been deserted for a period long enough to allow the exposed organisms to become completely rotted away; but to this point I shall refer more fully again. In this cut was got a fragment of one of those curious perforated stones which Mr. James Bennie found in the bed of the Clyde at Glasgow, see *Transactions* (vol. ii., p. 114), and which he supposed to have been used as "sinkers" for the fishing-lines or nets of the old Clyde canoe-men.

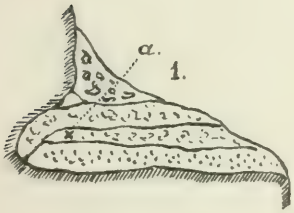
From the Ayrshire sands I have gathered several of these

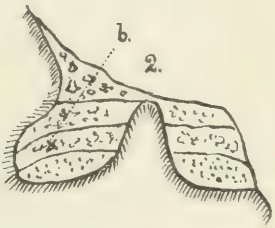


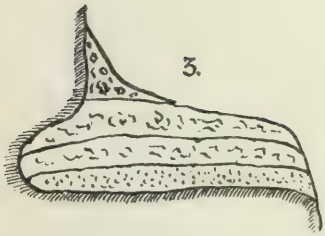
PLAN.

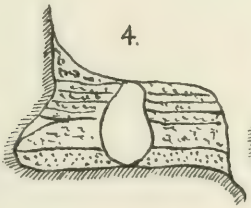
LONGITUDINAL SECTION.

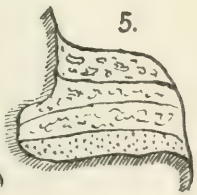
Level of Railway.











CROSS SECTIONS.

J. SMITH, DELIN.

ARDROSSAN SHELL MOUND.

CARTER & PRATT, LITH.

perforated stones, and, like this one, the holes have always been made from both sides, meeting in the centre. They are of two kinds, those made of stone, which appear to have been real sinkers, and those made of gas-coal, which are of the rudest description of workmanship, and the use of which is not so evident. My idea of these latter is that they were kept as charms, or perhaps reverenced and regarded as a sort of sleeping *fire-god* or *sun-god*, seeing that they were composed of a substance that would burn and flame. Of course, any beach pebble would have been more effectual as a sinker than one of these light pieces of gas-coal.

At the top of this section was got a piece of wheel-turned, glazed pottery. This was the first indication of a substantial advance in the arts, but, as we shall see further on, it belonged to a period posterior to that of the shell-mound. In the lower part of this cut were several fragments of a human skull; it had not parted by the sutures, but had evidently been smashed up to get at the savoury intellectual morsel within. One single valve of *Cardium edule* turned up here.

The next cut gave the following section:—

	Feet.	Inches.
1. Talus.		
2. Shell and bone layer	2	0
3. Reddish soil,	0	6
4. Shell and bone layer,	1	0
5. Earth,	0	0½
6. Raised-beach gravel, with large rolled stones,	1	0

After working round between a mass of fallen rock and the rock face, the next section was as follows:—

	Feet.	Inches.
1. Talus.		
2. Sandy soil, with pottery and slag,	0	6
3. Shell and bone layer,	1	0
4. Shell-meal,	0	2
5. Shell and bone layer,	1	0
6. Earth,	0	0½
7. Raised-beach gravel, with large rolled stones,	1	0

This last section gave us a new deposit—the sandy soil (2) with pottery and slag—which threw much-needed light on the relationship between the pottery and the slag, and showed very distinctly that their period was posterior to that of the shell-mound. All the pottery was of the wheel-turned description, and glazed; the slag was very dark in colour, and heavy. Both the

slag and the pottery were of the same description as those I have often found on the Ayrshire sands, and introduced us to a period when man was acquainted with metal and the use of the potter's wheel. The "bill of fare," as indicated by this bed, was not so rich and rare as it had been during the shell-mound period; with the pottery and slag were only got a few periwinkles and the bones of rabbits and hares.

It is interesting thus to be able to compare this later period with the shell-mound period; this never before could be done with data supplied by the shifting Ayrshire sands, which mix all the remains of the various ancient periods together. But I am inclined to think that there is still another period, if not two, awanting, viz., the flint period and the bronze period, and the time they occupied may be represented better by the next section, where 9 inches of *earth* come in between the pottery and slag-bed and the top of the shell-mound. Not a trace of flint was found in the shell-mound, nor in the pottery and slag deposit. The flint and bronze periods are well represented in Ayrshire, and it appears to me that these ancient periods should read thus—

1. Slag and wheel-turned pottery period (the most recent).
2. Bronze period.
3. Flint period, with arrow-heads, scrapers, &c.
4. Shell-mound period, with hand-made pottery.
5. Period of the 20 to 40 feet Raised-beaches.

The old hand-made urns, with burnt bones, flints, polished celts, and hammers, should probably be correlated with the flint period.

The last section (Plate XI., no. 5), at 12 feet from the upper end of the mound, was as follows:—

	Feet.	Inches.
1. Talus, earth and large pieces of sandstone.		
2. Decomposed shells, bones, and earth, with wheel-turned pottery, and slag,	1	2
3. Earth and bones,	0	9
4. Decomposed shells,	0	3
5. Shell-meal,	0	3
6. Earth,	0	0½
7. Raised-beach of sand and gravel,	1	0

This section was near the upper end of the mound, and the shells and bones were all in a decomposed state.

The last bit of the mound to be excavated was the part outside of the fallen rock (Plate XI., section 4), as follows:—

	Feet.	Inches.
1. Earth and shells,	0	4
2. Shell-meal,	0	4
3. Shell and bone layer,	0	2
4. Shell-meal,	0	4
5. Earth and shell layer,	0	6
6. Shell-meal,	0	2
7. Dark band,	0	0½
8. Earth and shell layer,	0	6
9. Shell and bone layer,	0	5
10. Earth,	0	1
11. Raised-beach bed, of sand and gravel,	1	0

This was by far the most interesting section of the whole, and afforded evidence that the mound had been deserted, for considerable periods, at least three times during its accumulation.

Throughout the extent of the mound were found a number of hammer-stones, a few very much worn, but the bulk of them had been little used.

All through the mound were found limpets having a hole perforated in the apex. Some were so much decayed that it was impossible to say whether these holes had been made artificially or by decay. Many had undoubtedly been made artificially, and it is most likely that they were strung like beads, possibly on to a strip of hide, and used as ornamental shell-belts, or *wampum*, after the manner of the Red Indians, for savage tribes, as well as more civilized ones, like to be "braw."

To Mr. E. T. Newton, palæontologist to the Geological Survey of England and Wales, I am indebted for the following list of animals, the bones of which were identified by him from a selection of 261, which I made from the whole mass of those found in the shell-mound, and which I sent up for his inspection:—

1. Man, *Homo sapiens*.

First rib, one.	Fragments of skull, four.
Second left rib, one.	Right radius, one.
Cervical vertebræ, six.	Left ramus with 4 teeth, fragments
Dorsal ,, two.	of one.
Lumbar ,, one.	Upper maxillaries, toothless.
Right mastoid, one.	Teeth, a few loose.

2. Long-faced ox, *Bos taurus*, var. *longifrons*. Mr. Newton thinks that the ox bones probably all belong to this species. Abundant.*

* From No. 2 onwards the species are given in the order of their abundance.

3. Goat, *Caper hircus.* Common.
4. Dog or Wolf, *Canis lupus* (*?*) ,,
5. Sheep, slender legged. ,,
6. Red Deer, *Cervus elephas.* ,,
7. Pig, *Sus scrofa.* ,,
8. Badger, *Meles taxus.* Frequent.
9. Rabbit, *Lepus cuniculus.* ,,
10. Roebuck, *Capreolus caprea.* Scarce.
11. Hare, *Lepus timidus.* ,,
12. Fox, *Canis vulpes.* ,,
13. Horse, *Equus, sp.?* ,,
14. Otter, *Lutra vulgaris.* ,,
15. Cat, *Felis catus.* ,,
16. Beaver, *Castor fiber.* Rare.
17. Weasel, *Mustela vulgaris.* ,,
18. Seal, *Phoca, sp.?* ,,
19. Grey Goose, *Anser cinereus.*
20. Pheasant, *Phasianus* (*?*) One doubtful bone.
21. Oyster Catcher, *Hæmatopus ostralegus.*
22. Red Grouse, *Lagopus Scoticus.*
23. Herring Gull, *Larus argentatus.*
24. Razorbill, *Alca torda.*
25. Puffin, *Fratercula arctica.*
26. Guillemot, *Uria troile.*
27. Conger Eel, *Conger vulgaris.*
28. Cod, *Gadus morrhua.*
29. Edible Crab, *Cancer pagurus.*

From the above list it will be seen that the Ardrossan shell-mound builders were no ordinary mortals, but a race of noble savages, monarchs of all they surveyed, hunters of the mountain bull, the stag, and wild boar, clothed during the winter months with the skins of some of the larger animals, and probably having their own tattooed. But they certainly were not the poor painted savages, grubbing up and feeding on roots and herbs, that certain authors, evolving "unwritten history" from their imaginations only, love to depict the ancient Briton. Their occasional diet of shell-fish may have been partly from necessity, partly to give a relish to their more substantial food, which, by all the evidence we can gather from the mound, must have been eaten raw; although we have seen that they were certainly acquainted with the use of fire.

On showing the list to a friend, he remarked that probably no "mixen" of the present day in the United Kingdom could show the evidence of a greater variety of food.

The only extinct Scottish animal, the remains of which were found in the mound, is the beaver. The two species of deer—the red deer, and the roebuck—would also probably have been extinct by this time had they not been protected. A number of the bones of the dog (or wolf, for anatomically it is impossible to draw a distinction between these animals) indicated individuals of large size. If they are bones of the wolf, of course this is another extinct animal. But if of the dog, it shows that these people had a powerful race of dogs, as well as horses (which, like the Tartars, they seem to have eaten, probably when they were done with them), with which to hunt their larger game.

It is astonishing to see the dog (or wolf) named amongst the more common species. Can the shell-mound men have eaten these animals? It is well known that some savage tribes at the present day feed their dogs on vegetable substances, so that during times of scarcity they may be used for food, their flesh by such feeding becoming palatable and wholesome, although when dieted on flesh it is rank and nauseous. In the present instance it is not within our knowledge what kind of vegetable matter they could have fed their dogs upon, there being no evidence in the mound that they were acquainted with any of the cultivated cereals.

The following is a list of the shell-fish found in the mound:—

Limpet, *Patella vulgata.* Abundant.
Periwinkle, *Littorina littorea.* ,,
,, ,, *obtusata.* Frequent.
,, ,, *rudis.* Rare.
Trochus lineatus, now extinct in Clyde. Frequent.
Silver Buckie, *Trochus umbilicatus.* Frequent.
The Groat, *Cypræa Europeæa.* One specimen.
Dog Whelk, *Nassa reticulata.* Frequent.
Roaring Buckie, *Buccinum undatum*, small shore variety. Frequent.
Dog Winkle, *Purpura lapilis.* Frequent.
Spindle Shell, *Fusus*, sp. ? A fragment.
Edible Mussel, *Mytilus edulis.* Scarce.
Spout-fish, *Solen siliqua*, of small size. A fragment.
Aitken, *Mactra subtruncata.* A few valves.
Oyster, *Ostrea edulis.* Scarce.
Edible Cockle, *Cardium edule.* Two valves.

From the above list it will be seen that in the matter of shell-fish the *piece de resistance* was certainly furnished by the two species, the limpet and the periwinkle; the former, generally speaking, prevailing in the bottom part of the mound, and the latter in the

upper. The other edible species are conspicuous by their scarcity, and two good edible ones, the "hugger-fish" and the "clabbydoo," are not represented. It will be observed that the rare or absent species are such as live in holes or under sand. Was the ancient Briton not acquainted with this fact, or were these molluscs scarce or absent from the district? From what has been already said I am inclined to hold the latter view. Two land shells were also obtained, *Helix nemoralis* and *H. nemoralis*, var. *hortensis*.

After the mound had been turned over, and the rain had washed the surface of the debris, I obtained a pair of bone needles or "aulds" which doubtless did good service at one time in sewing fur garments for the ancient Briton.

There is a considerable similarity between the jaw of a pig and that of the genus *Homo*. During the exploration, a person who assisted me picked up a bone, and observing him standing and looking at it with a mixture of curiosity and dread depicted on his countenance, I said, "What is this you have got hold of now?" His diagnosis was decided, as he at once replied, "a tremendous man's jaw." It was that of a pig!

I have heard it said that Professor Huxley at one time described a number of bones from a shell-mound somewhere in the north of Scotland, but I do not know in what publication his remarks on the subject are to be found.*

* Since the above was written I have had a note from Professor Huxley to say that he is not personally responsible for the cannibalistic theory mentioned in the paper referred to.

No. XXX.—On the Modern Manufacture of Ancient (?) Flint Implements, including an Interview with an Irish "Flint Jack." By James Neilson.

[Read 14th April, 1892.]

On two occasions last year business took me to the north of Ireland, where I utilised my spare time by visiting the Giant's Causeway and the district adjoining. On the first occasion I went by rail from Londonderry to Portrush, an enjoyable ride, during which most interesting views were obtained of the Antrim chalk cliffs with their basaltic caps. This most characteristic feature of the coast line of N.E. Ulster was best seen at Downhill and Castlerock, while the great Atlantic breakers, from a recent storm, rushing shorewards and bursting in snowy whiteness on the sandy beach, presented a scene of beauty hardly surpassable.

At Portrush we were transferred to the electric tramway car, having 8 miles still to go before reaching our destination. For the first 2 miles we skirt hills of blown sand, and then reach the exposure of strata known as the "White Rocks," the equivalent of the English chalk, and overlaid by basalt which has burnt them nearly as hard as itself. These "White Rocks" form a continuous series of sea-cliff for some miles, and appear to be from 60 to 100 feet in height. The action of the sea has worn them into extraordinary shapes, and a Scotchman may here see in a couple of hours as many rock arches as he would in a lifetime in his own country.

On a black cavernous rock, adjoining a fault which cuts off the chalk, stand the picturesque ruins of Dunluce Castle, with its narrow approach, and its buildings bearing a resemblance (when seen from a distance) to the well-known Dunottar Castle, near Stonehaven, on the Aberdeenshire coast. From this our road now becomes more tame as it runs inland, and shortly we arrive at the Giant's Causeway, the terminus of the car line.

On my second visit, starting from Belfast, we took rail to Larne, from which the journey was continued by means of long cars along the coast road as far as Cushendall, about 25 miles distant, thence inland over a mountainous road to Ballycastle, 16 miles, whence another drive of 13 miles brought us to the Giant's Causeway. By taking the electric car to Portrush, and rail to Belfast, the circle may be completed in an agreeable trip of two days.

On the Antrim coast road the scenery is sometimes magnificent, the great chalk cliffs with their basaltic covering being very impressive. In some cases we observed basaltic columns as large in diameter as those seen in Cathkin Quarry, while far surpassing them in length. At other places the occurrence of the Lias could be detected by its peculiar habit of breaking away from the main cliff, and forming an undercliff sometimes a mile long. Owing to this same habit of the Lias the roads even frisk about in a manner that would be positively dreadful in the eyes of our staid, old-fashioned roads at home.

At intervals, relieving and breaking up the long line of cliff, we pass the beautiful bays of Glenarm, Carnloch, Red Bay, Cushendall, and Whitepark, and the famous "Glynns" or glens of Antrim—foremost among which we have a splendid view of Glengarriffe, the queen of them all. From Ballycastle may be had a view of the magnificent headland of Fair Head, nearly opposite the Mull of Kintyre, while parts of the Scottish coast from Cairn Ryan to Islay are visible. This locality formed the ancient home of the Scots or Dalriads, and from here they crossed over to Cantyre, gradually making themselves masters of the country, to which they afterwards gave their name—Scotland, or the land of the Scots. We pass the old castle of Dunseverick, which is still pointed out as their chief seat, while under our eyes is the island of Rathlin, in which King Robert the Bruce found refuge during his time of adversity. Anyone who has taken this route will admit that it forms one of the finest and most enjoyable excursions to be found anywhere.

The geological formations brought under review during the journey may be classed in descending order as follows:—

Tertiary Basalt.	
Chalk, Greensand, Liassic Beds,	most of the way.
Triassic Rocks,	at Carrickfergus, Red Bay, &c.
Carboniferous Rocks,	near Ballycastle.
Old Red Sandstone,	near Cushendall.

It has been remarked that Arran is an epitome of the geology of the world, though the newer formations are not found there. From the above table it will be seen that Antrim fills up the gap. In strange contrast to Arran experiences, however, we are told that there are no dikes in Ulster.

Before entering on the more particular subject of this paper I must not omit to notice a visit to the rope-bridge of Carrick-a-rede. Situated amidst wild and grand scenery, and crossing a chasm some 60 feet wide and as many deep, the first sight of this bridge, as I saw it, was well calculated to take away one's breath. Two ropes stretched across the chasm supported a series of light wooden spars, on which a single 9-inch board formed all the footing, while, on one side only, a rope served the purpose of a hand-rail. The weather being stormy the bridge swung alarmingly, and my first feeling was not to attempt it, but, after waiting for some time, I came to two conclusions—first, that the bridge would not blow away; second, that I could hold on to the rope. For the first few steps I was all right, but near the centre a sudden squall set the bridge shaking so much that I had to stop and hold on tenaciously till it steadied. On reaching the island we found the fishermen were about to return, as they could not work on account of the storm. It was rather gratifying to my overstrained nerves to find that they waited for the wind to moderate before crossing to the mainland.

I shall not here attempt any description of the Giant's Causeway, but merely remark that though it may be seen from the sea or from the top of the cliffs, by far the most impressive view is to be obtained from a footpath which runs along the face for about 2 miles east of the Causeway proper. The guides try to frighten strangers by saying that the path is unsafe, but it is really not so, as the dangerous parts have been cut so as to render them safe for the passage of sheep. No guide is actually necessary, but I took one—Charles M'Allister by name—an obliging fellow and a good climber, who showed me the quarries opened in search of minerals. I could not but express my astonishment at their extent, and the dangerous positions in which many of them are situated. We climbed up together to one on the top of a sharp ridge of rock called the "Horse's Back"; and, however it may be with other articles sold at the Causeway, there is no doubt that the minerals represent good, hard, honest work, which deserves encouragement.

On my first visit (in spring) I was offered for sale numbers of flint arrow-heads, everybody having some to dispose of, and, there being at that time of year few tourists and little demand, prices were low. I bought a selection, but being rather suspicious of

the quantity for sale, I questioned everyone likely to be able to afford any particulars regarding them—guides, quarrymen, hotel folks, and visitors. In this way, bit by bit, I picked up a considerable amount of information, of which I now propose simply to give the result.

In the manufacture of flint implements the flakes were chipped off a round or many-sided flint nodule, row after row reducing it gradually till it was too small for further chipping, when it became a "core." In each flake the dividing ridge between the two flakes which had been chipped off immediately above it became the centre, so that it was thus somewhat thicker at its centre than at its edges. In some parts of the country such flakes, genuine remains of the old manufacture, are quite common. Probably the finer specimens only were selected to be fashioned into implements, the others being thrown aside. Another common implement is known as a "thumb scraper," as it is supposed to have been held between the thumb and forefinger when used to scrape the skins of animals in the process of curing, or to scrape down wooden articles.

I carefully examined a considerable number of the stone and flint implements offered for sale at the Giant's Causeway, and I was of opinion that, with the exception of the flakes and scrapers, I did not see a single genuine specimen; but that, like the cheap razors, they were one and all made to sell. Perhaps from this should be excepted one or two stone celts (not flint) and one stone hammer, which I thought might be genuine.

As was probably the case in olden times, celts and hammers are now made by grinding and boring stones selected from the beach for their resemblance to the required shape. So well are these articles now fashioned that it is impossible for an inexperienced eye to tell the difference, and even the best authorities are sometimes deceived. One lady told me that she had seen a gentleman (who shall here be nameless), considered to be one of the best judges of such matters, reject a flint arrow-head which she knew to be genuine, and accept another which, "with her own eyes," she had seen made shortly before.

Several persons in this neighbourhood were said to be manufacturers of flint implements, but all my informants united in awarding the palm to one man who was expected to come to the Causeway

on the following day, but who, much to my disappointment, did not turn up.

He was reported to make a good bit of money by his manufacture, but, unfortunately, could never keep sober if he had as much in his possession as would enable him to get drunk.

On the occasion of my next visit I made further enquiries regarding this individual, but at first could hear nothing more regarding him. However, on leaving the hotel in the evening we were followed by a tall, thin, gaunt-looking man, who accosted me with, "You were axing for me, sorr. I'm so and so" (mentioning his name, which I had previously heard). "Oh," I said, "are you the man who makes the flint arrow-heads?" He was, or pretended to be, surprised at my question, but finding I was well informed about the matter he no longer attempted concealment. I was therefore much pleased to find that I had at last got hold of the right man, and that I could get him to speak out, as I understood him to be the most famous "Flint Jack" in Ireland.

He gave me a long story about how his flints were to be found in all the museums and best private collections in the country, but, I presume, a considerable discount may be allowed for the "blarney" which springs naturally from the soil. He was very anxious to sell me a stone hammer which he confessed to having made himself, but I said that the only things I would buy from him would be flint arrow-heads actually made in my presence. At first he made some excuses about not having anything to make them with, but I gripped his jacket, and turning the edge told him he had something sewed on there for making them. On seeing that I was up in the particulars he unbuttoned his waistcoat and exposed a piece of strong leather sewed on inside, and then taking from his pocket some flint flakes he selected one and proceeded to form it into an arrow-head, using as a tool a pointed piece of basalt, and remarking that any stone hard enough for road metal was sufficient for his purposes. Holding the flake between his left thumb and forefinger, he pressed the point of the basalt against its edge, breaking off little chips and turning it over and over as he gradually worked it into shape, simply by pressure, the leather serving as a guard for the protection of his thumb. In the space of about four minutes he produced a barbed arrow-head, which would be not only quite suitable for its purpose, but which

might very well be mistaken for a genuine specimen of an ancient one. He also made various others during our interview. One thing which surprised me was, that he reserved the thickest part of the flake for the point of the arrow-head. I had been informed that he used a key to shape heavier flakes, but I did not see him do anything with such a tool.

In striking off the flakes from the mass he said that a stone did much better than a hammer, though, not having ocular demonstration, possibly this was said to please me.

Some of the arrow-heads had a green coating, which, like the verdigris on bronze, made them appear more ancient, and this, he said, was obtained by rubbing the specimen on a "docken." Stone hammers after being made were burned in a peat fire to give them a brown, old look.

I may say that I have tried to make some arrow-heads myself, but the flakes I had were not of the thinnest, and I discovered that the left thumb required a strength of muscle which mine had not got, and which, I presume, would take a considerable amount of practice to develop.

I believe this man does a lot of his preparatory work at Bushmills old quarry on the way to Portrush, where, by the way, he told me there are plenty of fossil sea-urchins.

This enterprising individual's manufactures did not end with stone hammers. He was very anxious to make me an urn, which, however, would take two days, but would, he said, be undistinguishable from an ancient one, and the cost would be five shillings. He did not obtain an order from me, but I afterwards saw some baked clay urns offered for sale at this price, and I have no doubt these had a similar origin. I believe that more of the same kind may still be had by any member of the Society who is desirous of possessing an undoubted specimen of the "rale genuine ancient urn"—of modern manufacture.

No. XXXI.—A Visit to the Island of Little Cumbrae, with some Notes on its Minerals. By James Neilson.

[Read 12th April, 1892.]

Although the Island of Little Cumbrae must be perfectly familiar —by sight at least—to every member of the Society, I am afraid that only a few have ever set foot on its lonely shores. This arises not so much from its comparative inaccessibility as from a mistaken notion that, amid so much surrounding beauty, the "Wee Cumra" is hardly worth a visit. It will, however, be found that the rocky island has charms all its own, and differs so much in almost every respect from the other Clyde islands and from the neighbouring mainland that it may, as a whole, be described as unique.

The lover of the lonely who walks its shores or glens may here indulge to the full his feeling of *monarch-of-all-I-survey-ishness*. For the archæologist there are prehistoric remains — early Christian church ruins and graves; the foundations of what is said to have been a round tower; cairns supposed to have been raised over Norse warriors slain in the battle of Largs; an old castle of historic times; and an old lighthouse perched on the summit of the hill. Several of the caves are believed to have been at one time inhabited, and in a rocky recess on the shore near the northern point is what I take to be the remains of an ancient kitchen-midden yet awaiting exploration.

Nor is the interest afforded by the Little Cumbrae less to the geologist. Its terraces present possibly one of the best examples of that stair-like appearance from which the name *trap* is derived, the various overflows of igneous rock rising over one another and breaking off sheer at their edges. There are several varieties of trap, some being amygdaloidal, while others, comparatively compact, contain large cavities lined with various minerals. Some of these cavities are as much as a foot in diameter, and are lined with a peculiar milky variety of quartz from 1 inch to 2 inches in thickness, the insides being apparently entirely empty. The inner surfaces of this lining present large mammilations closely covered with small crystals.

Many other cavities found in these rocks are filled with calcite or various kinds of zeolites, including analcite, white

stilbite, and red heulandite. Localities for this latter mineral—heulandite—are now almost unknown in the West of Scotland,* and it is therefore interesting to know of one station where it can certainly be found. The visits I have paid to the island have been too short to enable me to thoroughly examine all the rocks, but I have found heulandite among the stones on the beach about half tide, at the northernmost point of the island, Sheannawally Point, although not *in situ*. It is, however, common at Gull Point, the most southern point of the island, where it may be got amongst fallen rocks on the beach, or *in situ* in the rocks of the cliffs above. The specimens I have found are all more or less weather-worn, and so do not show the crystals to advantage, but if the rock were quarried doubtless fresh specimens could be obtained. Cluthalite, which was originally described as a separate species by Thomson in his "Outlines of Mineralogy, &c.," 1836, is found here in abundance. It is now included in the species Analcite, and is not even mentioned either as a variety or a synonym in the "Catalogue of Western Scottish Fossils," 1876, nor yet in Dana's "Manual of Mineralogy." "Reddish white" is the nearest approach in Dana's description of analcite to the colour of cluthalite; it is better described by the "flesh red" of Thomson. As it is apt to be mistaken by the student who is only familiar with the ordinary varieties of analcite, it seems to me that it would be more convenient to retain the old distinctive name. Small specimens of chalcedony are also found here, though rarely.

If the weather is calm the visitor to the island may leave his boat among the rocks opposite Gull Point, but if there is any swell on the water it is better to land at the bay near the old castle and walk. Although there is hardly a footpath even, and the road is both rough and occasionally wet, still there are many objects of interest to repay the trouble. You walk along the level terrace of the old Raised-beach under the rocky cliffs, some of them very fine, and pass within sight of the Split Boulder figured by Mr. Smith of Jordanhill, in his well-known work.† After some time we come to a place where the Raised-beach terminates, and the cliffs come down to the sea. These rocks are traversed by

* See paper by Dr. Forster-Heddle in *Transactions*, vol. ix., part 1, p. 72.

† "Researches in Newer Pliocene and Post-tertiary Geology." 1862.

several dykes which have been cut out by the waves, leaving narrow passages 30 or 40 yards long by as much, sometimes, as 20 feet deep and 2 or 3 feet wide, through which we continue our way.

Gull Point itself is a high rocky point, approaching so close to the sea that there is only room for a narrow pathway between it and high tide mark; while high up on the face of the cliff there is a beautiful rock-arch. Under this the zeolites may be found in detached fragments on the beach, while immediately round the end of the point they may be found in a more compact rock *in situ*.

The walk may be continued along to the New Lighthouse, where the cliffs are higher and more impressive. Several large caves are passed on the way. If the boat has been left near the castle the return journey may be made over hill, with a visit on the way to the Old Lighthouse on the highest point of the island.

In any case the visitor should not leave without seeing the solitary graveyard on the top of the cliff two or three hundred yards west of Gull Point. It is somewhere about 4 yards square, and originated in a girl desiring to be buried there. The story is that when her sweetheart went to sea, she came every day and sat on this cliff to get the earliest glimpse of his returning ship; but hope deferred made the heart sick—she pined away and died, leaving as her last request that she might be laid to rest in this lonely spot. I am afraid, however, that the early age recorded on her tombstone renders this story more than problematical.

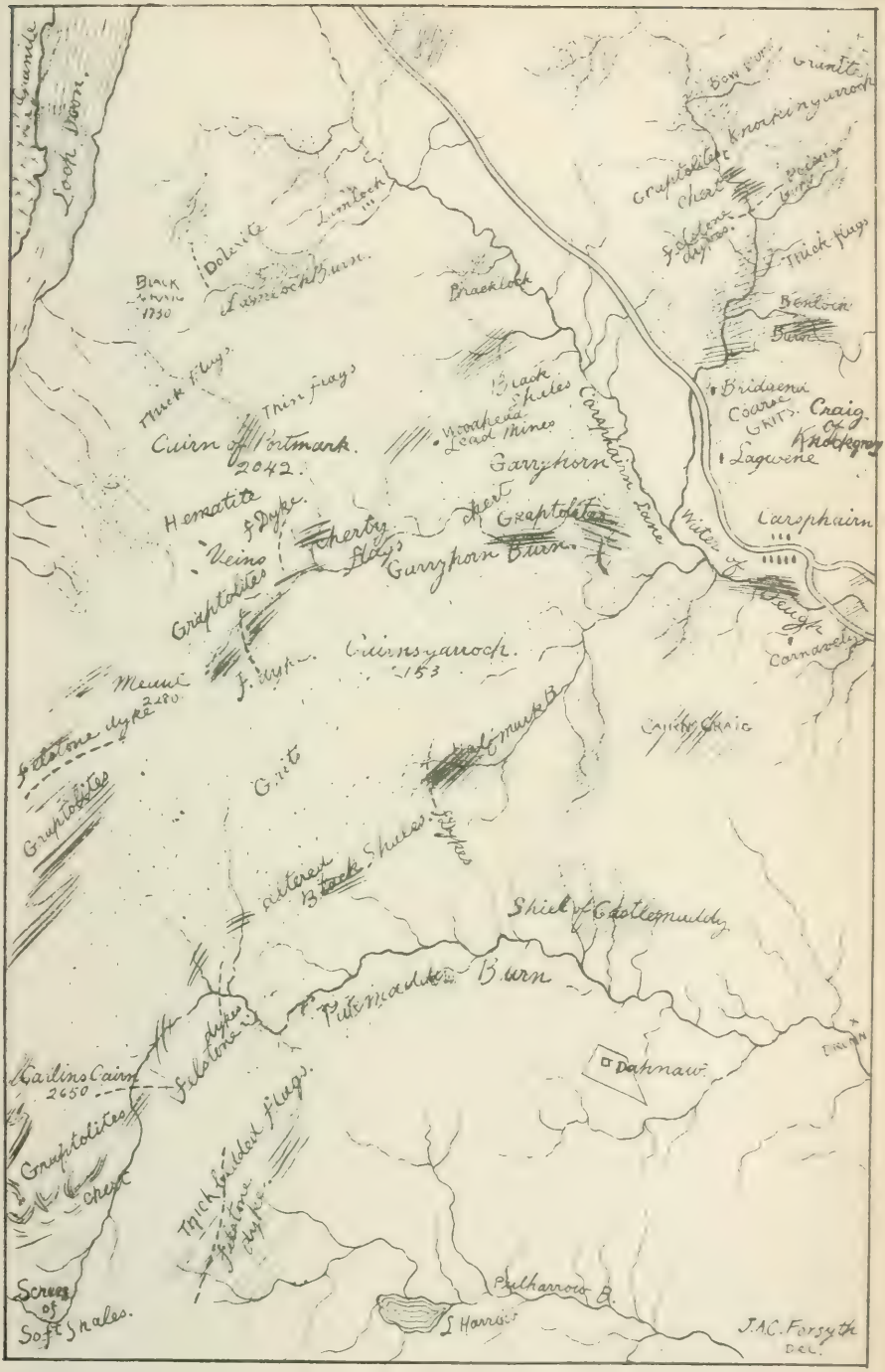
No. XXXII.—The Geology of the Carsphairn District. By David Forsyth, M.A., D.Sc. With Two Plates [Nos. XIV. and XV.]

[Read 14th Jan., 1892.]

I. *General Description of the District.*—The parish of Carsphairn forms the borderland between Ayrshire and Galloway, and consists of the upland valley of the Deugh, flanked on each side by mountains—the highest in the Southern Highlands of Scotland. This mountain district may be regarded as supplying the head waters of the Ken, which flows in a generally southern direction till it enters Loch Ken. On leaving Loch Ken it is joined by the Dee, which in turn gives name to the united streams as they pass on to Kirkcudbright bay. The district can be reached, therefore, in two ways—by New Galloway and Dalry from the south, and by Dalmellington from the north, about 10 miles distant. The latter route is the most frequented, if we can use such a term for roads in such mountain solitudes. The road from Dalmellington to Carsphairn is of great geological interest, as from it may be seen good sections of the three great formations of Southern Scotland —Carboniferous, Old Red Sandstone, and Silurian—it therefore merits a brief description.

On leaving Dalmellington the road follows one of the numerous tributaries of the Doon; and the traveller is soon interested in the well-preserved "moat," and in the numerous sections of sandstones, shales, and thin-bedded coals, so characteristic of the Carboniferous formation. Two very good examples of the displacement and alteration of strata by one of those dolerite dykes, so common in this coalfield, also occur on the roadside and in the adjacent burn.

Soon is reached the region of the Calciferous Sandstone, where the strata are manifestly uptilted towards the S.E. against the southern mountain ridge—that sinuous line of elevation which stretches across Southern Scotland, and in this district always gives two drainages, the one N.W. and the other S.E. Although the point of immediate contact is concealed by the alluvial débris of the stream, the observer notices at a very short distance a complete change in the strata; reddish coloured or purplish flags, and rudely stratified conglomerates take the place of shales and sandstones, and the dip of the beds is towards the S.E. Evidently this is the line of the great fault which separates the Old Red



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MAP OF CARSPHAIRN DISTRICT.

Scale 1 in. = 1 mile.

Sandstone on the N.W. from the Ayrshire Carboniferous strata of Girvan and Straiton; just as a second fault separates the Old Red Sandstone from the southern Silurians. Numerous porphyritic and felspathic beds are interbedded with these sandstones, and in a few places are to be seen instances of the metamorphic action of those intrusive pink felstone dykes so characteristic of this southern area. In three places, also along the side of the burn, are found thin veins of hematite, staining the surrounding rocks, and discolouring the water. These veins seem to lie along the *dip plane* of the strata—a method of occurrence which will be mentioned again when I speak of the Silurian area. These rocks have yielded me no fossils, as, although some thin-bedded mudstones did look likely localities, they proved most disappointing in results.

A still greater change soon awaits the traveller. About 3 miles from Dalmellington the road passes through quite a mountain gorge with steep escarpments on each side, the strata consisting of grey-blue flags, with an outcrop from S.W. to N.E., and an inclination, sometimes of 60°, to the S.E. They have all the external characteristics of the southern Silurians; and possibly the gorge was first hollowed out from the higher grounds to the south by ice, and then by the subsequent action of running water the ravine was deepened. All the rock-surfaces from which, by any chance, vegetation has been recently removed give evidence in grooves and striæ of glacial action. As the burn crosses the strike nearly at right angles many excellent sections are seen, but the absence of fossils prevents any systematising of the strata; although there are not wanting many physical evidences that the thickness of the formation here is not so great as one would suppose, but that the sections are rather repeats, by contortion and plication, of the same strata.

On gaining the top of the ridge, between the road and Loch Muck, glacial striæ on the surface of the projecting knobs of ground are seen, their general direction being to the N.W. or N.N.W. The loch itself has all the appearance of an ice-scooped basin, partially filled by debris and vegetable growth. From the side of the loch is obtained quite a panoramic view of the southern mountainland, and the great hollow occupied by Loch Doon (although the loch itself is not visible at this point), flanked on each side by massive mountains, such as Meaul and Carlin's Cairn,

and in the distance by Merrick, the highest summit in Southern Scotland.

After passing the crest of the watershed the drainage is towards the south, the principal stream being the Carsphairn Lane, a sluggish stream which "winds its weedy way" till it joins the Deugh; and, although at a few places shales are seen, it exhibits no striking sections in its whole course. Yet the valley is not without points of geological interest—moats, as the "Strife Moat" at Lamford (where, tradition says, disputes used to be settled by appeal to arms), at Brockloch, and Daltallochan; and also kames and moraines. The ridge at Cadger's Hole projects across more than half of the valley, and seems to have dammed back an old loch, whose waters afterwards breached the mound.

The contour of the country leads me to think that such mounds are mostly due to the excessive denudation following the glacial age—that in fact they are "rubbish tips" made by tributary streams. Nor should one forget the pleasing contrast of Lamloch—like a fairy dell in the midst of the lone wilderness—a little nook in which are gathered all the floral treasures of the district.

As we approach the village, the Deugh is crossed by a picturesque bridge, near which the thick-bedded blue-grey flagstones and massive grits present a striking contrast to the scenery of Carsphairn Lane. A fine avenue of old trees opens up the first view of the village, seen nestling at the foot of the hills, and the weary traveller soon finds a welcome at the hospitable Salutation Inn.

II. *Special Description of the District.*—Carsphairn is a small, clean village of one street, lying cradled amongst hills. As already stated, the joint valleys of the Deugh and Carsphairn Lane notch the hills by a trench-valley running from north to south, while to the east and west the hills rise rapidly from the village. To the east the craig of Knockgray rises to the height of 1250 feet, affording a fine view of the whole district; and behind it, still further to the east, in a series of grand swells, towers the mighty mass of Cairnsmore of Carsphairn (2612 ft.), so called to distinguish it from its lower rivals of the same name, Cairnsmore of Dee and Cairnsmore of Fleet. West of the village street is an alluvial flat, composed of large gravel washed down by the Deugh and its tributaries; while immediately west of the Deugh the ground begins to rise rapidly into a series of secondary ridges—

Cairnsgarroch (2153 ft.), Craigneldie (2000 ft.), and Craigrine (2000 ft.). Again these are backed to the westward by the mighty rampart of the Kells range, where the prominent summits are Coran of Portmark (2042 ft.), Meaul (2280 ft.), Carlin's Cairn (2650 ft.), and Corserine (2668 ft.), overlooking the deep trench in which lies the rock-basin of Loch Doon. On each side, also, of the Carsphairn valley there is a granitic boss—Cairnsmore to the east—and another, to the south-west of the Doon valley, stretching from Craigmalloch to Merrick—the mountain nucleus from which spring the Girvan, the Stinchar, and other streams. Between these two bosses the strata are grits, flagstones, and shales, their strike being generally from S.W. to N.E. These abut in their course against the granitic masses without much deflection or contortion, and on the other side of the outburst resume their usual direction and monotony of structure. The granitic bosses seem, therefore, either to have been volcanic "outblows" through the older sedimentary strata, or, perhaps with greater probability, volcanic intrusive masses from which subsequent denudation has removed much superincumbent material. Such outbursts have of course produced much change in the adjacent rocks, but the metamorphism is very varied in amount and in kind

One type is well illustrated round Cairnsmore, where the whole of the strata immediately surrounding the central mass are altered by what might be termed *contact* metamorphism, so that sandstones and conglomerates become altered into quartzites, and mudstones become hornstones or lydianstones. But this metamorphism is not always uniform, for I have often traced Silurian flagstones close up to the granitic boss without noticing much alteration, and in many cases no change is apparent at 100 yards from the igneous rock. Nor yet is the metamorphic area so large as one would expect from so great a granitic nucleus, for it seldom extends a mile from the granite.

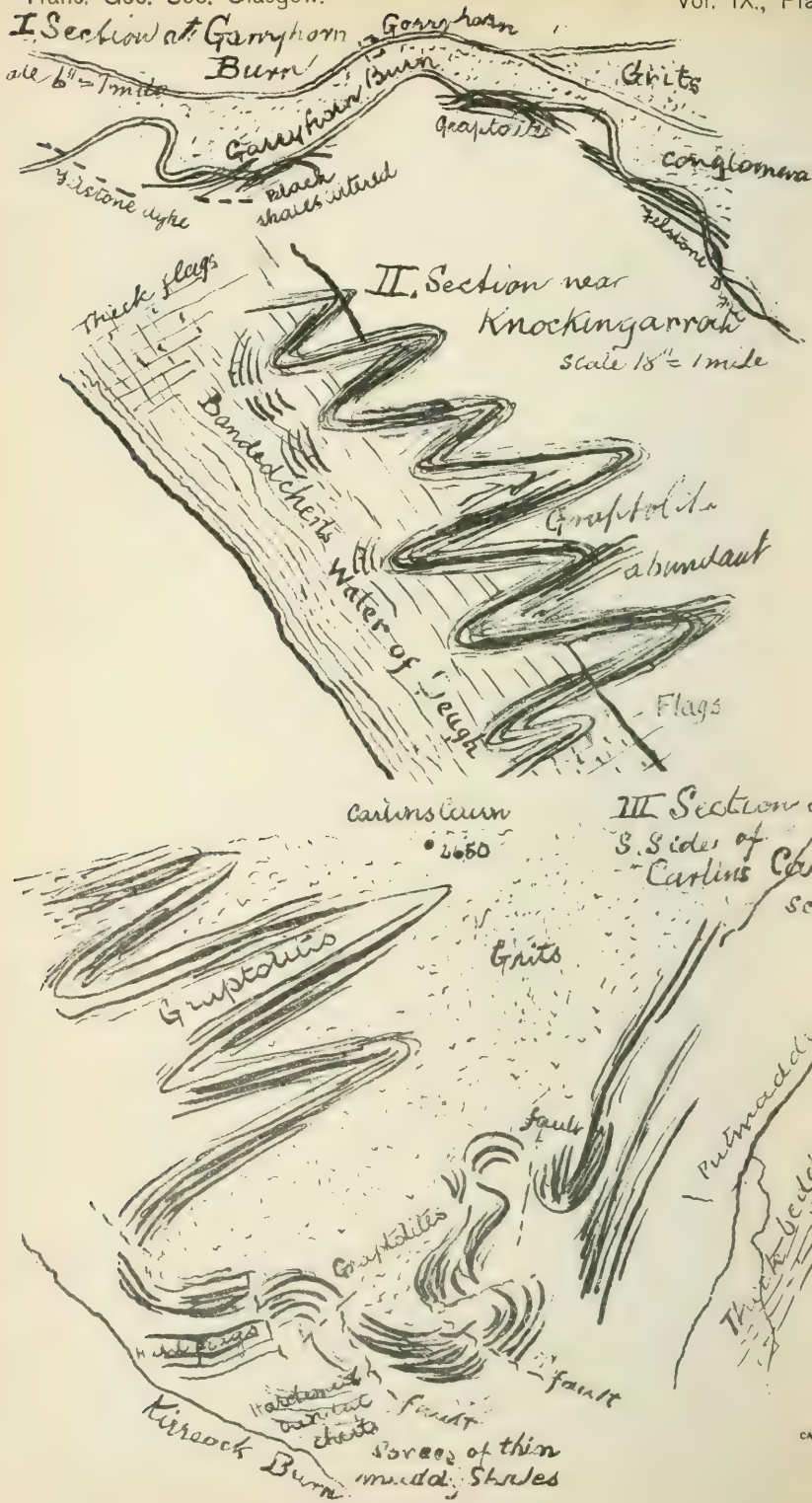
Another type of rock-metamorphism is seen in the influence of the numerous felstone dykes which intersect the sedimentary rocks in all directions throughout this area. These dykes can be traced like fingers, stretching out from the granitic centre altering on each side the character of the aqueous rocks, and giving them not only a hardened crystalline character, but entirely changing their appearance and mineral structure. One area of grits on the

W.S.W. side of Meaul looks more like a micaceous schist or gneiss than a grit, from the prevalence of a black-brown mica amongst the crystalline matrix. Indeed, I have fallen into the habit of calling them *granitoid grits*, as best expressing the internal structural change which has been produced.

These black shales afford excellent examples of a third kind of metamorphism. From contortion, pressure, and heat-contact they are so altered that in some districts they cleave into blocks like basalt; in others they have the appearance of a black dolerite, with grains of quartz; while in others, from possibly the destruction of graptolitic remains, they have the shimmery, scaly appearance of graphite.

III. *Geological Structure of the District.*—In such a district as this, where, at first sight, the sedimentary rocks present a remarkable monotony of appearance, suggestive of no arrangement, and of enormous thickness of deposit, there are but two guides to an intelligent understanding of its geological structure—(1) the following out of a formation easily recognised and fairly persistent; and (2) the mapping out of the fossiliferous beds. In this district the grits supply the first or lithological index, and the black shales or graptolitic shales the second or palæontological test. The Carsphairn grits extend in a general S.W. to N.E. direction from Carlin's Cairn, by Cairnsgarroch and Knockgray, to the shoulders of Cairnsmore, forming in contour two oval-shaped masses, connected by a narrow isthmus of alluvial land. The graptolite shales are closely connected with these grits—often appearing to come from below them, and always following them in endless sweeps and curves through all the variable surface conditions of height and hollow. [See Plate XIV.]

The Deugh and its tributaries cut across the general line of strike at varying angles, and this, along with the twistings of the strata themselves, render the mapping of the district a task of extreme intricacy, and often of a misleading nature; while the tracking of the graptolite beds often leads one down into deep dells, and then to the crests of ridges fully 2000 feet above sea-level. But the ever-varying prospects, the sweet nooks, as at Lamloch and in Half-mark Burn, the refreshing breezes, and the successful finds, are ample compensation for the toilsome climbs and the drenching showers of this upland country.



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IV. *Sections.*—A. *West of the Deugh and Carsphairn Lane.*—One of the nearest sections to Carsphairn is that shown in Garryhorn Burn [Plate XV., section 1], and in some of its features it is quite characteristic of the structure of the country. At the foot of the burn, near its junction with the Deugh, are found flagstones and grits. At the first footbridge occurs a conglomerate, which at some parts exhibits a brecciated structure. Further up the burn occur black shales, much altered and glittering like graphite, often containing iron pyrites, but no fossils. On the opposite bank of the burn the same shales are less altered, and graptolites are found, being succeeded to the left by thick flags, which dip beneath them at 60° to the N.E. A felstone dyke, seen here in the bed of the burn, accounts for the metamorphism of part of the shales. Above the Garryhorn farmhouse the felstone dyke appears again in the bed of the burn, and is here bounded on both sides by black shales, altered to hornstone, but with no fossils. The felstone is in some parts compact and crystalline, and in others quite earthy, with lenticules of shale included. At a still higher point in the burn the shales are so altered as to break under the hammer in square blocks like jaspery lydianstone. This section seems to indicate that under the grits and conglomerates runs a bed of black shale with the thick flags below it. The graptolites found here are :—

Lasiograptus costatus, Lapworth.
Dicranograptus ramosus, var. *elongatus*, Lapworth.
Didymograptus superstes, Lapworth.
Dicellograptus sextans, Hall.

B. *Cairnsgarroch Section.*—For a long distance after this the Garryhorn Burn passes over marshy, alluvial land, in which the superficial covering hides all sections. To the right, however, are the ruins of the works where, at Woodhead, lead was mined ; and among the débris I constantly found specimens of black shales, but with no fossils. Among the same heaps I found specimens of elvanite, syenite (or granite, in which hornblende replaced mica), and on the sides of the Bow hill many boulders of syenite lie scattered.

In the Garryhorn Burn, above the waterfall, is a very interesting section ; a felstone dyke, which crosses the burn twice, alters the grits into a kind of *granitoid* rock, and the shales into bands

of flinty hornstone. In this section the black shales lie N.E. of the grits, and are succeeded by thick-bedded flags. The same black shales can be traced in two or three projecting hummocks on the face of Bow hill, at a height of 1600 feet; but they are much altered and contorted, and have no graptolites. A very fine section is found on the steep N.W. face of Cairnsgarroch, about 1800 feet above sea-level. The upturned black shales have an outcrop from S.W. to N.E., and dip below the grits at a very high angle towards the S.E. The shivered débris forms screes down the steep mountain side, sometimes rendering the footing dangerous, but the abundance and variety of the graptolites are ample reward for the risk. The forms most commonly found are :—

Didymograptus superstes, Lapworth.
Dicranograptus ramosus, Hall.
„ „ var. *spinosus*, Lapworth.
Pleurograptus linearis, Carruthers.
Climacograptus bicornis, Hall.

The succession here is the same as that in the Carlin's Cairn sections (to be afterwards mentioned); but this area is remarkable for the metamorphism in some parts. Some specimens of grits are quite granitoid, and the thinner flags are altered to jaspery hornstones. Nor should mention be omitted of three or four openings which have been made for hematite in the southern and western slopes of Bow. The hematite seems to occur in thin veins along the plane of the bedding of the flags, and the openings are made along a ridge about 1900 feet high.

The magnificent panoramic view obtained from this ridge cannot be passed without remark. The spectator, 2000 feet above sea-level, stretched on the short wind-swept heather after his steep upward climb, rests his eyes on the wide prospect, as I did on my last visit, when Loch Doon

> "In all her length far winding lay
> With promontory, creek, and bay,
> And islands that, empurpled bright,
> Floated amid the livelier light,
> And mountains that like giants stand
> To sentinel enchanted land."

Beneath my feet lay the long expanse of the loch, with its islands seen from that elevation, *almost in plan*, and with the old castle mirrored in its calm waters. Towering in front rose Merrick and

Shalloch, blue in the distance, with the gleamings from the waters of Loch Macaterick and Loch Finlas lighting up the dark hollows. To the geologist the map-like picture of the effects of denudation —seen in the hummocky hills, and in the rock-basin lochs—was a profound and suggestive lesson. From this height the contrast between the two sides was most marked, the trench-like valley, occupied in part by the loch, but extending also considerably further south, seemed to form a line of division between two different rock-formations, which had been acted on by one and the same agency.

C. *Meaul and Carlin's Cairn Sections.*—Following the long narrow ridge between Bow and Meaul I found abundant shivers of graptolitic shales immediately to the west of the summit of Meaul and about the level of 2000 feet. The shales had the usual strike, from S.W. to N.E., but the specimens, owing to the small exposure of rock, and the weathering to which they have been subjected at such a height, were not in good preservation. The principal fossils are :—

Pleurograptus linearis, Carruthers.
Diplograptus euglyphus, Lapworth.
Diplograptus quadrimucronatus, Hall.

Rather less than a quarter of a mile S.E. of these shales there occurs an altered grit presenting the most remarkable form of metamorphism that I have seen in this district. The structure of the rocks has been so much altered as to become largely crystalline, and the change has led me to speak of them as "granitoid grits."

Quite close to this place there is an extensive exposure of graptolite shales, due, I think, to quick flexures in the outcrop, whereby the apparent thickness of the strata is greatly increased. These shales continue to the south-west along the shoulder of Carlin's Cairn, keeping very much about the level of 2000 feet. There are few exposures of any great depth and the succession is therefore not easily made out ; but, from such as are visible, grits seem to extend along the whole ridge to the east, and thick-bedded flags towards the west of the black shales. The forms found amongst the shales include—

Pleurograptus linearis, Carruthers.
Didymograptus superstes, Lapworth.
Diplograptus quadrimucronatus, Hall.

To the south of Carlin's Cairn occurs one of the most remarkable

sections of the whole district. The area embraces a semi-elliptical ridge immediately south of the cairn, and the exposures are such, on all three sides, as to show not only excellent sections of all the strata, but to indicate clearly their relation to each other. The grits occupy the hump of the ridge, and, sweeping round and between, with many a sharp flexure or more gentle contortion, lie the graptolitic shales; while to the extreme south of the semi-ellipse there is an exposure of banded or cherty flags, reminding one of the "calmy" shales of the Ardwell shore, near Girvan. This resemblance is still more remarkable from the screes, on the steep shoulder of Craigtarsen, which are composed of shivers of thin muddy shales, reminding one of the lower Ardmillan series of the same locality, south of Girvan. The steep ravine of the Pulmaddy Burn lays bare the entire succession—grits, black graptolitic shales, and flags. Graptolites occur in abundance all round the ridge, and fine specimens are obtained amongst the freshly-broken material of the screes on the sides. The shales are crossed by the Pulmaddy Burn, lower down, in three places; but only in one of the localities did I obtain graptolites. In the others the presence of a felstone dyke (of a beautiful pink where washed clean by the burn) accounts for the contortion of the shales and the absence of fossils. This dyke has all the look of a continuance of one near the head of the same ravine, which stands out in pink relief along the plane of stratification, against a high scaur of grey flagstones. The same altered black shales occur in the Goat Burn and Blaree Burn, with no graptolites, and with the accompanying felstone. Along the same line black shales occur in the small burns and drains, running down from the south-east of Cairnsgarroch, and also in the Pulterrson and Half-mark Burns, and always in the same relation to the grits; but in none of these localities have I found graptolites, even after a prolonged search. The thick-bedded flags to the south-east of the Pulmaddy ravine present no special features, except the grandly precipitous north-east face of Craignelder Gairy. The fossils found are :—

Climacograptus bicornis, Hall.
Diplograptus apiculatus, Lapworth.
Diplograptus Whitfieldi, Hall.
Dicranograptus Nicholsoni, Hopkins.
Dicranograptus ramosus, var. *spinosus*, Lapworth.
Didymograptus superstes, Lapworth.

I am under the impression that this graptolitic band is continuous with the lower Garryhorn section, and that the upper Garryhorn and Bow sections are continued, greatly disturbed and contorted, and without fossils, towards Woodhead, along the S.E. face of Coran of Portmark, and that *somewhere* it crosses the Carsphairn Lane between Brockloch and Daltallochan. If such be the case, and scant and scattered evidences of black shales are found all the way, then this completes the survey of the district to the west of the Deugh, except a small patch immediately west of the schoolhouse, close to the water of Deugh, a manifest continuation of the Garryhorn section.

North of this area Coran of Portmark and Black Craig are composed of thick-bedded flags, with, at rare intervals, thin shales or flags. Overlooking Loch Doon, at the west side of Black Craig, are several large blocks of granite perched on the steep hillside at an elevation of 1400 feet. On the face of Little Craig is a dolerite dyke slightly altering the surrounding flags, which are again exposed in the pretty little dell of Lamloch. The black shales of the Woodhead section are continued in the Green Burn, a tributary of the Carsphairn Lane, opposite the farm house of Brockloch, but I have found in them no graptolites.

II. *Sections to the North and North-east of the Deugh and Carsphairn Lane.*—Immediately north of and behind the village is the rough circular mound-like Craig of Knockgray (1256 ft.), which is composed of coarse grits, more like those of Meaul than any others in this area. To the south-east, in the Knockgray Burn, are sections of thin flags and muddy shales; but in this direction I did not find any black shales, although I examined the ground very closely for the continuation of the shales of the Garryhorn and Deugh. Still further to the south-east lie the thick-bedded flags which, starting from below the Liggat Bridge, seem to extend in outcrop from S.W. to N.E. all over the hill-country of Dunool and Beninner; but, although sections are frequent in the tributary burns, and black shales interbedded among the flags occur at intervals, I could not find any evidence as to geological relation, nor as to whether the great apparent thickness from Liggat Bridge to Deugh was due to plication of strata or not. In this part felstone dykes are numerous and exercise the usual metamorphic effects on the circumjacent rocks. In Moorbrack and Furmisten

the dykes are quarried and the boulders are utilised for curling-stones.

D. *Sections in Benloch Burn.*—West of Knockgray Craig, near Bridgend, there is a section of thick-bedded flags extending for fully 100 yards on each side of the bridge; and further up the Deugh are found beds of black shales, thin, contorted, and very much altered, glittering, like those of Garryhorn, with black carbonaceous particles, and with a good deal of iron pyrites diffused through them, but yielding no specimens of graptolites. In the Benloch Burn the same thick-bedded flags appear as in the Deugh; but after crossing the ridge there occurs a thick bed of black shales, a good deal contorted and much discoloured with iron, tilted on edge, with a general strike to the N.E. but dipping towards the S.W. This bed, from its position in relation to the neighbouring grits, seems to be the representative of the graptolite shales in Garryhorn, Meaul, Carlin's Cairn, &c., but after diligent search it yielded no graptolites.

Proceeding up the burn, grits, black shales, and thick-bedded flags succeed each other. Interbedded among the thick flags are occasionally thinner beds with thin black shales, and this succession continues up to the "black shoulder" of Carsphairn. As boulders in the bed of the burn banded cherty flags are seen, and their presence led me to expect a section similar to that of Carlin's Cairn, but I have not yet been able to trace them to their original position.

E. *Sections in Polsue Burn.*—The sections in this burn are similar to those in Benloch, black shales being succeeded by thin flags, and these again by thick-bedded flags as we proceed up the burn, but I did not find any graptolites. Towards the head of this burn an interesting junction of Silurian flags and shales with the granite of Cairnsmore is seen. The alteration in the aqueous rocks is slight until close to the granite, when they become much hardened; but the thin finger-like projections of granite veins into the flags present more variety, for not only are the thin flags and shales very much altered, but the character of this granitic vein is very much changed, losing its crystalline and assuming a more earthy nature, besides losing its special grey colouring and becoming a dull white earthy felspathic rock.

F. *Knockingarroch Section.*—On the Deugh, a short distance

south of the shepherd's house at Knockingarroch, an excellent exposure of black shales is exhibited. The section [see Plate XV.], extends for about 180 to 200 feet, and although in that distance the bed is sharply flexured three times, graptolites are very abundant and in fine preservation, particularly close to the bank of the burn in the first and second curvatures. To the south this bed is succeeded by thick flags, which, at the junction of the Polsue Burn, are as hard and as resonant as dolerite. In the bed of the Deugh, immediately to the west of the graptolitic shales, are seen two small exposures of banded cherty flags. The graptolites found in this locality are—

Dicranograptus tardiusculus, Lapworth.
Dicranograptus ramosus, Hall.
Dicellograptus sextans, Hall.
Climacograptus bicornis, Hall.
Leptograptus grandis, Lapworth.
„ *simplex*, Lapworth.
Lasiograptus bimucronatus, Nicholson.
Lasiograptus costatus, Lapworth.
Cœnograptus gracilis, Hall.
Cryptograptus bicornis.
Glossograptus Hincksii, Hopkins.
Didymograptus superstes, Lapworth.
Diplograptus euglyphus, Lapworth.
Diplograptus foliaceus, Murchison.
Cryptograptus tricornis, Lapworth.

To the N. and N.W. of this locality, drained by the Deugh and its tributaries, the prevalent strata are thick-bedded flags, sometimes merging into grits and conglomerates, and often crossed by felstone dykes; but I have met with no fossiliferous beds which would aid one to arrange the succession of these upturned flags, alike monotonous in their arrangement, colouring, N.E. strike and S.E. dip. They are evidently the same strata which, on the other side of Carsphairn Lane, form the mass of Coran of Portmark and Black Craig.

Summary.

My first conclusions regarding the district were:—1. That the thick-bedded flags to the north-west and south-east form the lips

of a synclinal basin, and correspond to the Dalveen and Lowther beds of the north of Dumfriesshire ; and here they are so thickened and so similar in appearance that it seems impossible to separate them. The great ridge of the Kells, including Coran of Portmark, Meaul, Carlin's Cairn, Meikle Craigtarsen, Craigrine, and possibly some of the other hills, are composed of these flags.

2. That basined in this syncline is a lenticular mass, or, it may be, masses, of grits, stretching from the summit of Carlin's Cairn, and Meaul, by Cairnsgarroch, Garryhorn Rig, Craig of Knockgray, and Dunool, to the side of Cairnsmore. The sections exposed in the western part of this elongated ellipse show clearly the succession, but the absence of characteristic graptolites in the black shales of the eastern part allows of a little dubiety. Still, when we consider the contorted character of much of this area, it is possible that repeated visits and more diligent search may enable us to place this area on the same footing of certainty as the other.

3. The shales which almost constantly come between the grits and the flags contain the characteristic graptolites of the Glenkiln series or Hartfell series.

But more careful consideration of the palæontological evidence afforded by the graptolites has led me to modify my opinions.

(1) From the constant occurrence of the typical Glenkiln and Hartfell graptolites in the same shales, and the absence of graptolites in other beds, it seems as if these two zones in the Carsphairn area come together without any intervening flags or sandstones.

(2) From the persistence of certain forms (*Didymograptus superstes*, *Dicellograptus sextans*, and *Dicranograptus tardiusculus*), one side of the shale bed seems to be Glenkiln, and the other side, from the prevalence of equally typical forms (*Diplograptus quadrimucronatus*, *Leptograptus simplex*, and *Pleurograptus linearis*), seems to be Hartfell.

(3) Under these circumstances the Carsphairn grits would occupy the central dome of an anticline, and form the lowest rocks of the district, corresponding possibly with the Barr conglomerates, and flanked by the newer Glenkiln and Hartfell shales, and these in turn by the thick-bedded Dalveen flags.

(4) The muddy shales of Carlin's Cairn and Knockgray are interpolated between the black shales and the flags and correspond to the Ardwell beds.

(5) And the banded cherty flags which so regularly accompany the black shales may be the representatives of the Stinchar limestone. Perhaps another search along the shoulders of Dunool and Cairnsmore may give the same relations as occur at Carlin's Cairn.

The district of Carsphairn is one of great geological interest as one of the sources of the ice-borne granite blocks which dot the surface of south-western Scotland. But my notes on this and its other glacial phenomena I shall reserve until I can more thoroughly examine Cairnsmore, and the district between it and Cairnsmore of Dee, a wild region which I have had only once or twice a peep into, while the Merrick district must form the connecting link between the Girvan and Barr series and this Carsphairn area.

To all members of the Society I would urge the claims of a region, attractive in many ways; remote from the ordinary track, the traveller meets with thorough kindliness and cheap entertainment at the clean and hospitable village inns; the fisher enjoys ample scope for his gentle art; the botanist gathers rare specimens among the undisturbed solitudes; and one and all who visit this southern land of mountain and lake find, in healthful change, points of resemblance and contrast between it and its more majestic, and better known, but scarcely more picturesque, rival, the Northern Highlands of Scotland.

In concluding this paper I would like to express my indebtedness to Dr. Lapworth for valuable assistance in naming the graptolites of the district.

No. XXXIII.—A Reverse Fault in Kiltongue Coal at Drumshangie Colliery. By Robert M'Laren, Inspector of Mines.

[Read 11th February, 1892.]

Reverse faults are of rare occurrence, and consequently in coming across one at the above colliery, I took notes with a view of bringing it before the members of this Society. The Drumshangie Colliery is situated to the north-east of Airdrie, in the county of Lanark.

The owners are Messrs. Drumshangie Coal Co., and the certificated manager is Mr. William Stevenson.

The extent of the field is 200 acres, and the Kiltongue coal is found in 120 acres; fully three-fourths of which has been worked. The field is intersected by a large throw of 40 fathoms, running south-east and north-west.

The Kiltongue coal lies in the upper coal measures, about 30 fathoms below the famous Airdrie blackband ironstone.

No. 1 pit, in the workings of which the fault was got, is sunk to the Upper Drumgray coal, at a depth of 46 fathoms, and Kiltongue coal in south section is reached by a cross cut mine.

The seam is worked longwall, with walls 14 yards long, and average inclination is 1 in 15.

A section of the seam is as follows :—

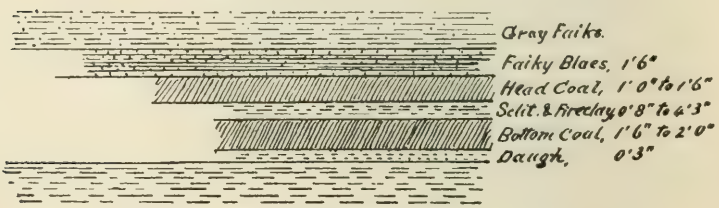


Fig. 1. *Scale ⅛ inch = 1 foot.*

In working the coal 20 yards from the large throw a hitch was met running north-east 60°. The side of the greater angle was lying off on the top, apparently showing an upthrow, but on cutting the "vees" it was found to be a reverse fault with a throw downwards. The hitch began at almost nothing, and where the throw was greatest it measured 2 feet. As it went to the rise it thinned off. The angle of the "vees" was small, being 30°.

In coming towards the fault the rise was 5°, and inside it the rise was 14°.

The following section shows the position of the throw.

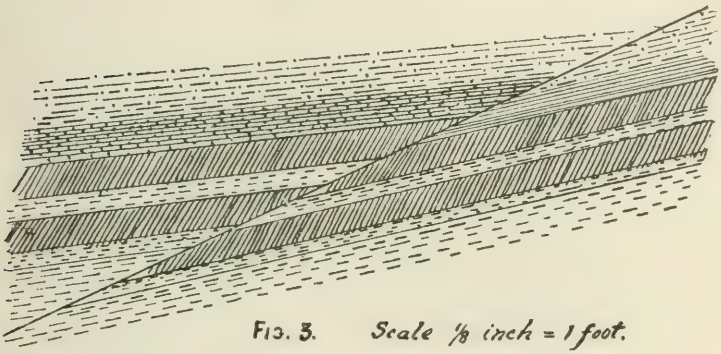


FIG. 3. *Scale ⅛ inch = 1 foot.*

Throughout the seam various disturbances have been met with in proximity to the large throw, and it is evident this reverse fault is due to the same cause.

The origin of reverse faults has recently been clearly demonstrated by Mr. H. M. Cadell in a series of experiments made by him, the results of which have been given in a paper read before the Royal Society of Edinburgh.* This paper with its experiments was also delivered by Mr. Cadell before this Society [see *Transactions*, vol. ix., part 1, page 228]. These experiments show that reverse faults are produced by horizontal pressure.

* "Experimental Researches in Mountain Building," by H. M. Cadell, Esq., B.Sc. *Transactions of the Royal Society of Edinburgh*, vol. xxxv. part 7.

No. XXXIV.—Notes on the Geology of Fife. By the Rev. Alex. S. Wilson, M.A., B.Sc.

[Read 12th May, 1892.]

The county of Fife lies between the firths of Forth and Tay, and forms with Kinross a rectangle 36 miles in length by 14 in breadth. The total area of the two counties is about 600 square miles, and the coast-line extends to 85 miles. Through the middle of the county, for the greater part of its length, runs a hollow—the Howe of Fife, in the eastern half of which the river Eden flows, discharging itself into St. Andrews Bay. From Loch Leven the river of the same name issues, and after an easterly course of 12 miles falls into Largo Bay. Along the northern boundary to the west are the Ochil Hills, which are continued eastward as a ridge of moderate height between the Eden and the Tay, one of the peaks, Norman's Law, being 850 feet. North-east of Loch Leven are the Lomond Hills, 1713 feet; Largo Law, 1020 feet, is a conspicuous landmark on the bay of that name, and to the east of this Kelly Law rises to 800 feet. The Cullalo Hills, near Aberdour, attain a height of 750 feet, while the Cleish and Saline Hills, of similar height, are situated in the extreme west of the county. The surface of Fifeshire generally is undulating, exhibiting considerable variety, and the scenery in many parts is highly picturesque.

The geological map of Fife might be represented by a *tricolor* flag, the three horizontal bands corresponding to the three great formations of which the rock-strata of the county are built up. The northern strip is entirely occupied by great sheets of interbedded trap, variously designated whinstone, greenstone, felstone, and porphyrite. The middle belt of the county is formed of rocks belonging to the upper series of the Old Red Sandstone period. Loch Leven, Kinross, Strathmiglo, and Cupar are situated on this central area. The southern zone, which is the widest of the three, consists of strata belonging to the Carboniferous period, interrupted here and there by outbursts of igneous rock associated with patches of volcanic tuff and breccia. Taking them in order, we have the three bands running east and west:—

I. The northern zone of Interbedded Trap or Porphyrite.
II. The middle zone of Old Red Sandstone.
III. The southern zone of Carboniferous strata.

I. The rocks of this northern zone are continuous with the traps composing the Ochil Hills, and form the eastern portion of the great belt of volcanic strata which stretches across Scotland from S.W. to N.E., through the counties of Renfrew, Dumbarton, and Stirling, into Fife. Known as the great trappean conglomerate, this belt includes rocks which belong to different ages. The trap rocks of Scotland have been formed at very different times—periods of intense volcanic activity alternating with long ages of inaction. During the early part of the Old Red Sandstone period the central district of Scotland was the scene of volcanic phenomena on the grandest scale. Miles on miles of country were deluged with fiery floods of molten lava, or buried under showers of scoriæ and volcanic dust—the Pentlands, the Ochils, and the Sidlaws being built up of successive sheets of consolidated lava erupted during this period. Then followed a long epoch of tranquillity, throughout which our Scottish volcanoes remained dormant, and the deposition of the stratified rocks of the Old Red Sandstone formation proceeded without interruption.

The succeeding age, to which belong the calciferous sandstones forming the base of the Carboniferous system, witnessed a renewal of volcanic activity. In this era the volcano of Arthur's Seat came into existence, throwing out the streams of basalt and porphyrite and showers of ashes which have formed the lower portion of that well-known hill. The traps of the Lennox and Kilpatrick ranges, the hills of Renfrewshire and North Ayrshire, the heights between Bathgate and the Forth, beds of tuff and porphyrite between Haddington and Dunbar, and possibly also similar accumulations near Burntisland, date from this time.

Above the calciferous sandstones lies the mountain limestone series. While the strata comprising this second division of the Carboniferous system were being laid down there existed numerous active volcanoes scattered over the central area of Scotland. During part of this period the greater portion of what is now Fife must have presented the appearance of an archipelago of volcanic islands, each fringed with its reef of coral, like groups of islands now existing in the Pacific Ocean. The eruptions became less frequent during the deposition of the millstone grit, and a period of comparative tranquillity succeeded, during which the true coal measures, forming the uppermost division of the Carboniferous system, were accumulated.

Along the coast of Fife there are numerous isolated bosses, necks, and veins of trap, indicating that some at least of the volcanic cones of the Carboniferous period continued to manifest activity down into Permian times. The troubled condition of the coal strata furnishes conclusive evidence on this point. At the historical and far-famed Hill of Beath the trap has burst up through the limestone series, and the coal seams through which it passed are burnt for some distance round. The structure of the hill is that characteristic of a volcano; there is the central vent, containing a plug of lava encircled by beds of tuff formed of débris expelled from the volcanic orifice. The Lomonds, Largo Law, Kelly Law, and many lesser hills throughout the county also date in all probability from the time of the mountain limestone.

Early in Permian times volcanic action all over Scotland subsided; the masses of rock and tuff which had been thrown up from the earth's interior began to be worn down by atmospheric denudation, and the softer parts were removed, exposing the harder central stumps of the extinct volcanoes. Of these, Arthur's Seat, a typical instance originating in the calciferous age, remained dormant, according to Sir A. Geikie, all through the remainder of the Carboniferous period. In early Permian times it broke out again, but from that period till now has remained inactive, though it would hardly surprise a geologist to learn any day that Arthur's Seat was once more in an active state of eruption.

There is no subsequent record of volcanic action in Scotland until we come down to Miocene times, and this represents an immense interval of time, for between the Permian and Miocene formations lie the whole of the Mesozoic strata, together with the Eocene beds. It may be accepted as certain, however, that during the protracted period in which the New Red Sandstone, the Jurassic Series, the Chalk, and the Eocene strata were in course of formation no active volcanoes existed in Scotland. In the meantime all the species of plants and animals had changed; the old forms had become extinct, and had been replaced by entirely new races. But the volcanic forces, though so long dormant, had not permanently ceased; in the Miocene age a fresh outburst on a grander scale than ever took place. This

time the greatest masses of lava were poured out on the western shores of Scotland. The basalts of the Giant's Causeway, Staffa, Skye, and the inner Hebrides are of Miocene age, these hardened lava floods attaining in Mull a thickness of over 3000 feet. Nor was the disturbance confined exclusively to the west, for all over Scotland there occur numerous trap dykes, generally running east and west. These have originally filled vertical fissures into which the melted lava was forced from below, passing up through the various horizontal beds. This lava solidified as it cooled, and long afterwards, in cases where the softer sedimentary strata, through which it rose, had been removed by atmospheric denudation, remained in the well-known form of a trap dyke. Such dykes of Miocene lava breaking through the sedimentary strata occur in all parts of the Fife coal-fields. A good example may be seen close to the shore, not far from St. David's.

The great belt of igneous rock which traverses the centre of Scotland from east to west, though continuous on the map, includes traps of various ages. The main masses west of Stirling, forming the Fintry, Campsie, and Kilpatrick ranges, and the traps of the Renfrewshire hills, belong to calciferous times; while the Ochils and the interbedded traps covering the northern zone of Fife, belong, on the other hand, to the earlier age of the Old Red Sandstone. From the circumstance that volcanic products are found interstratified with sedimentary rocks, we infer that the volcanic eruptions which threw up the former were contemporaneous with the deposition of the strata among which these volcanic products occur. These interbedded traps are well exposed in Glen Farg, through which runs the new railway route to Perth; they are also well seen near Newburgh station on the line to Ladybank.

Nearly all the hills of Fife are of trap, at least in their upper portions. This is apparent even from a distance, for the long level or slightly sloping lines and step-like terraced sides and ends outlined against the sky cannot be mistaken. But while the larger sheets are contemporaneous and interbedded, the smaller masses of later date are generally intrusive and break through, violently disrupting the subjacent rocks, which, from the effects of heat, are altered at the points where they come in contact with the trap. The older lavas differ in chemical composition from

the more recent; the former being acid and containing excess of silica, while the latter are basic. They differ also in their mode of weathering—Abbey Craig, Stirling Castle, and Craigforth furnishing examples of concentric greenstone. Of similar character is the intrusive dolerite at North Queensferry, which weathers into rounded masses, often forming almost perfect spheres. This rock is extensively quarried for causeway and kerb stones. Good examples of jointing and very marked lines of ex-filtration may be seen in some of the quarries. Cavities are occasionally found filled with crystals of calc spar, or sometimes with bituminous matter having a naphtha-like smell, derived doubtless from the beds of shale through which, in a fluid condition, the rock was ejected. The island of Inch Garvie, on which rests the central cantilever of the Forth Bridge, is a narrow ridge of the same dolerite, rising abruptly from the bed of the Forth, which at this point is of great depth. A mile or so westwards, opposite the anchorage of St. Margaret's Hope, the dolerite gives place to dark-coloured basalt having the characteristic conchoidal fracture. On the beach at Rosyth Castle the basalt may be seen, its surface showing innumerable lines of cross fracture.

As has been pointed out by Sir A. Geikie, the traps of Carboniferous age in Fife and the Lothians occur as small isolated masses, while those of corresponding age in the western counties form extensive beds. Such isolated bosses and necks are very numerous along the shore, particularly in the east of Fife. On the beach between Elie and St. Monance may be seen several instructive examples of volcanic necks or vents, filled with basalt, or in some cases with agglomerate. The space occupied by volcanic rocks in the middle and southern zones is, however, small relatively to the total area, but the northern belt, with the exception of a narrow fringe of Old Red Sandstone strata on the south-side of the Tay, is entirely taken up by the interbedded traps which, as we have seen, were poured out by volcanoes at the beginning of the Old Red Sandstone period.

II.—The middle zone is formed of rocks belonging to the upper series of the Old Red Sandstone, and, in the valley of the Eden, these beds are exposed at a number of places. Not far from Dairsie station there is a fine section of cliff composed of massive yellow sandstones. The road passes between the river and the

cliffs, which are about 60 or 70 feet high, while Dura Den, a beautiful spot and classic ground to geologists, is close by. These yellow sandstones have yielded numerous specimens of fossil fish, *Holoptychius*, *Glyptolepis*, *Pterichthys*, &c., and form the subject of a monograph by the late Rev. Dr. Anderson of Newburgh. The seam from which the fish were obtained lies along the bed of the stream. On the slabs preserved in the Edinburgh Industrial, in the Hunterian of Glasgow, and other museums, the fish occur in such numbers as to indicate that they perished suddenly. Exactly similar fossils have been obtained from the Heads of Ayr. During a recent visit to Dura Den the writer did not succeed in finding any ichthyolites but had the consolation of learning from a native that there were "plenty o' fine trout in the burn."

On the adjoining heights, from which one obtains a magnificent view of the Howe of Fife, are extensive freestone quarries where plant remains occur in great abundance. The thin uppermost seam is a veritable exhibition in black and white, but unfortunately the impressions soon fade when exposed to the action of the air. Casts of *Lepidodendron*, *Lepidostrobus*, *Calamites*, and others, possibly *Cordaites*, or perhaps the leaf stalk of a fern, are to be found in these quarries. *Stigmaria*, with the rootlets attached, is very frequent; these rootlets leave smooth groves in the fine-grained sandstone which might easily be mistaken for worm-tracks.

The yellow sandstones of Dura Den correspond with the Elgin beds from which the remains of fish belonging to the same genera have been obtained. The occurrence of reptilian remains in the newer Elgin beds is, however, indicative of Triassic age, and there is reason to suspect that these latter lie unconformably upon the Old Red Sandstone group below. Fish remains are also not uncommon in the lower division of the Old Red series to which the flagstones of Forfarshire and Caithness belong; and from the Carmyle quarries the remarkable crustacean *Pterygotus* is obtained, of which a magnificent specimen is preserved in Arbroath museum. The Old Red strata seem to have been deposited in a great inland lake, or possibly series of lakes, formed by the gradual shallowing of the Silurian seas.

III.—All the four main divisions of the Carboniferous system

are represented in the southern zone of Fife. If a line be drawn from St. Andrews due south to Elie, all the triangular area to the east of this, as far as Fife Ness, consists of rocks of the calciferous sandstone group, with the exception of a small tract at St. Monance and Pittenweem. This small area is occupied by a part of the Carboniferous limestone series let down among the calciferous beds. In it there occur a number of coal seams, but of so poor a quality that they have been abandoned. Passing westwards along the coast, from Elie to Largo, we are on the mountain limestone series; from Largo to Pathhead we cross the Dysart coal basin, belonging to the upper coal measures. At Pathhead a narrow band of millstone grit is passed, and at Kirkcaldy we are again on the Carboniferous limestone. At Kinghorn and Burntisland there occur great masses of porphyrite with interstratified tuff, and between this and North Queensferry we return to the calciferous series. At the latter place, a great mass of intrusive dolerite has burst up through the calciferous shales and sandstones. The overflow has formed the massive beds of whinstone, 150 to 180 feet thick, which surround Inverkeithing Bay, and also the Ferry Hills which jut out into the Forth, contracting its channel by a half. On the outer edge of this mass of dolerite the northern piers of the Forth Bridge are built. When first seen by the writer the beach at this point vividly recalled a part of the shore at Catania on the coast of Sicily, where a lava stream from Mount Etna has entered the sea, the scenery of Fife generally, as viewed from the Forth, being Sicilian in character. West of the Forth Bridge the limestone group reappears and continues on to Culross; to the west of which, near Dunimarle, we get the Castlecary limestone and the millstone grit. Beyond Blair Castle the slaty-band ironstone comes in, and the Kincardine and Alloa coals, which belong to the upper or true coal measures.

We thus see that along the south coast section there are two principal areas of geological elevation, viz., in the extreme east of the county and on the portion between Burntisland and the Forth Bridge; on these areas the low-lying Calciferous series is thrown up to the surface. The general dip of the strata agrees with these main undulations, though there are frequent lesser foldings, and in many places, the strata are faulted and disrupted. Inland, the main faults run east and west; in the Dunfermline

district there are four principal faults, ranging from 10 to 100 fathoms, by which the strata are thrown up towards the north. In general, the strata dip to the north, and as a result of the step-like faulting we meet, in passing northward, the same seams cropping out again and again.

(1.)—The calciferous series consists largely of flaggy sandstones, varying in colour from white to purple, and usually bearing ripple marks, with occasionally, the impressions of raindrops. These sandstones are well seen on the shelving shores at St. Andrews, Aberdour, and Rosyth. The shales, which attain a thickness of more than 100 feet, correspond with the oil shales so largely developed across the Forth in Linlithgowshire. From the shale oil is extracted at Binnend Works near Burntisland. This shale crops out again at North Queensferry, where it is traversed by a seam of clay-band ironstone.

A cliff near Rosyth Castle, consisting of thin beds of shale and compact earthy limestones, strongly recalls the Ballagan beds of the Campsie district, which also belong to the horizon of the calciferous or cement-stone series. Thin limestones occur here and there; of these the most interesting is the Newbigging seam, between Burntisland and Aberdour. This limestone is the equivalent of the Burdiehouse seam, and consists entirely of entomostracan remains. It is clearly a fresh-water deposit, and, from the appearance presented by the myriads of little *Cypris* cases of which it is made up, gets the name of seed-cake limestone. At various points between Kinghorn and St. David's occur masses of a peculiar volcanic breccia containing plant remains. This rock has evidently been formed out of pieces wrenched from different strata as the result of numerous explosions, for it consists of angular fragments of sandstone, *cypris* limestone, shale, and coal, cemented into a kind of concrete, sometimes hard enough to be used for building purposes. It may be seen in the immediate vicinity of the new pier at Aberdour. From it have been obtained many specimens of petrified wood in which the minute structure is admirably preserved. Fossil stems (*Lepidophloios*, &c.) from the porphyrite tuff of Burntisland have been made the subject of several interesting papers by Professor Williamson of Manchester.

On the whole, organic remains are scanty in the calciferous series, though scales of ganoid fish, and those doubtful structures

known as conodonts, supposed to be the jaws of annelids, are found in some parts of the shale. The general character of the group points undoubtedly to a fresh-water origin; like the rocks of the Old Red Sandstone, the calciferous series must have been deposited either in an inland lake or in the estuary of some mighty river. The thickness of the series has been estimated at 2000 feet.

(2.)—The Carboniferous limestone series covers a larger proportion of Fife than any of the previously mentioned groups. It consists mainly of sandstones, coals, shales, and limestones, the limestone which forms its base being quarried in many places. There are large works at Charleston from which great quantities of lime are annually shipped to various markets. The rock is here over 50 feet thick; it contains 92 per cent. of calcic carbonate, and abounds in fossils, corals—*Cyathophyllum*, *Lithostrotion*, and *Zaphrentis* being among the number—and various species of *Productus* and *Crinoidea*. From the Calais Muir quarry, north of Inverkeithing, some species of *Orthoceras*, and heads of the crinoid *Poteriocrinus* have been obtained. In Roscobie quarries, north of Dunfermline, fossils representing a marine fauna of the most varied description abound, and of these a goodly collection is to be seen in the Smith Institute at Stirling. Very fine septaria, with pyrites containing traces of copper, are abundant in the marly shale at Calais Muir, and lead ore has been obtained in small quantity near Inverkeithing.

The Dunfermline coal-field, which extends from the Cullalo Hills on the east to the Saline Hills on the west, forms part of the mountain limestone series, and is thus equivalent to the Possil and Maryhill coals of the Glasgow area. It has been worked for over 600 years. In 1291, a charter was granted to the Abbot of Dunfermline by the proprietor of Pittencrieff, conferring the privilege of working a coal pit on that estate. About the middle of the fifteenth century an Italian, Æneas Sylvius, who afterwards became Pope Pius the Second, relates that when visiting Scotland he saw the poor people, who in rags begged at the churches, receiving for alms pieces of stone with which they went away contented, adding that they burn them instead of wood, of which their country is destitute. Boetius, referring to Scotland in an account written early in the sixteenth century, states that

there "black stones are dug out of the ground which are very "good for firing, and such is their intolerable heat that they melt "iron and are therefore very profitable for smiths and other "artificers in metals."—(Chalmers' "History of Dunfermline," vol. i. p. 20).

The principal seams are known as the Dunfermline Splint or 4-foot, the 5-foot, and the 8-foot seams. In the Wallsend basin a 7-foot seam comes in above these, while the Little Splint, No. 3, the Ironstone, and Parrot form a still higher group, occurring in various pits. At the Elgin Colliery, a shaft of 105 fathoms passes through nineteen workable seams of coal, making an aggregate of 50 feet. This section shows 111 seams of alternating shale, sandstone, and coal, including altogether twenty-seven coal seams with a total thickness of 57 feet. Eastward, at Lochgelly pits, there are found in descending order, a 14-feet coal, the Lochgelly Splint and Parrot, the Mynheer, and the Splint, while at Donibristle we have the same series, with the limestone and calciferous rocks, cropping out on the flanks of the Cullalo Hills. From the last-named colliery have been obtained specimens of coal which were found by the late Professor Balfour to consist entirely of the spores of plants belonging to *Lycopodiaceæ*. Teeth of *Megalichthys* have occasionally been found in the Elgin and Halbeath pits. Seams of blackband ironstone occur in Townhill, Cowdenbeath, and several other pits, and near Oakley, to the west of Dunfermline, there were formerly extensive iron-works, but the furnaces have not been in operation for over twenty years. The Kirkcaldy series, also belonging to the Carboniferous limestone period, includes—in descending order —the millstone grit, thin coals, limestone, coal, Rough coal, Splint, the Duddie Davie, Black, Parrot, Upper Smithy, and Lower Smithy coals. On the St. Monance and Pittenweem area there are seventeen thin coal seams and five limestones, the latter with an aggregate thickness of 37 feet. In the extreme west of the county at Torryburn and Preston Island there is the following series:—Blackband, Lowrie Graham's, 6-foot, 9-foot, 5-foot, and 2½-foot seams. Preston Island, with its ruined buildings, forms a picturesque landmark in this part of the Forth. The seams just mentioned are inclined at a very steep angle, recalling the edge coals of Portobello. There is an old shaft on the shore near

Torryburn which must formerly have communicated with the one on the island, for there is a well known story connected with it. King James VI. of Scotland was taken down on one occasion by his courtiers and when brought up to the daylight through the shaft on the island, seeing the water all around him, his suspicious nature gave vent to itself in the exclamation, "Treason! Treason!"

A little further west, in the flagstaff park at Low Valleyfield, we come on the outcrop of the Cowglen or "Index" limestone. West of this again, and still higher up in the series, are the outcrops of the Janet Peat coal and limestone. The latter is identified in the Survey with the calmy, Arden, or Hurlet seam. The strata at this point have been thrown into folds, and the dip changes rapidly; a trough is formed, and the Janet Peat limestone, which crops out just behind Culross Townhouse, is again encountered at Blair burn, further west. This seam occupies the same horizon as the Robroystone limestone which crops out in George Square, Glasgow. Beyond Dunimarle we get the Castlecary limestone and the millstone grit, west of which lies the Clackmannan and Alloa coal basin, where occur the Upper 5-foot, the 9-foot, the Cherry, and the Splint coals, all belonging to the true coal measures.

On comparing the Carboniferous limestone series of Dunfermline with the corresponding strata of the Edinburgh or Glasgow districts, one is struck with the paucity of limestone in the former. No limestones have yet been found in the upper coal measures of the Glasgow district, so in this respect the Dunfermline basin, though belonging to the lower, rather resembles the higher series. It would appear that during the latter part of the mountain limestone era the deeper water lay to the westward, and that the Dunfermline area was occupied by a shallow lake or estuary, on which the accumulation of river sediments took place, the conditions being unfavourable to the formation of calcareous strata.

(3) The millstone grit covers but a small part of Fife. West of Dysart is a narrow strip running north to a point west from Thornton, and we do not meet with it again till near Kincardine, where it occupies Culross Moor and Tulliallan forest. Its strata consist of the characteristic coarse-grained sandstones and fine quartz conglomerates.

(4) The upper or true coal measures in the Dysart basin include eighteen seams, known as Wemyss Castle; Wall; Barn Craig, 5′ 6″;

Upper Coxtool, 3′ 6″; Lower Coxtool, 3′; Den, 2′ 2″; Chemiss, 9′; Bush, 3′ 6″; Parrot, 2′ 3″; Wood Coal; Earl's Parrot, 2′; Bowhouse, 6′ 6″; Brankston, 4′; Boreland; Shandwell; Dysart Main, 21′; Clayband ironstone, 2′; and the 7-foot coal. Inclusive of the lower seams of the limestone series, we have a theoretical aggregate thickness of 120 feet of coal on this area. When we compare the Dysart series with that of Dalkeith, the general correspondence points to both areas having once formed part of the same basin. The Dysart Main seam of 21 feet, for example, may very well correspond with the 15 feet seam at Portobello, while a 7 feet seam forms the base of both series. As a whole, however, the beds must have thinned out towards the north, for a section in one part of the Edinburgh field passing down through 3000 feet of strata reveals fifty-eight coal seams, with a total thickness of something like 150 feet. The equivalents of the Dysart series are to be found in the district east of Glasgow—*i.e.*, at Rutherglen, Shettleston, Bothwell, Coatbridge, and Airdrie, all situated on the upper coal measures; the Upper Soft, Ell, Main, Humph, Splint, and Virgin coals of the Bothwell pits, and the Blackband, Musselband, Virtuewell, and Drumgray seams of the Airdrie pits being their representatives in the western coal-field.

The number of these Dysart and Dalkeith coal seams, as well as their total thickness, may well induce us to pause and reflect on their geological significance. A coal seam approximately represents an old land surface, being composed for the most part of the remains of terrestrial plants, which cannot grow without air and light. When, then, a coal seam is discovered at a depth of 3000 feet, this affords conclusive evidence that the land has been depressed to something like this extent. But fifty or more coal seams may be superposed one above another, with beds between them of sandstone and shale which could only have accumulated under water. All this could, of course, be explained on the theory of alternate elevation and depression of the land level. Such oft-repeated alternations are not indeed impossible, but it is much simpler to suppose that it was brought about by the continuous sinking of the coal area. The formation of a coal basin may be accounted for in some such way as this—first, we may suppose that over a certain extent of land surface a quantity of vegetable matter sufficient to form a seam of coal had accumulated;

next, that by depression this area became submerged, and was buried under sand and mud brought down by river action from the neighbouring land; that this sediment continued to be deposited until the depressed area was completely silted up and the river confined to a narrow channel. In this way the level would be restored, and, vegetation again taking possession of the ground, material for the second coal seam would in course of time be formed. This process repeated time after time would ultimately, as the subsidence continued, give rise to a series of strata like those of which the Carboniferous system is built up. But the lapse of time, which a system many thousand feet in thickness, and formed in this way, must represent, transcends the powers of imagination to grasp.

The upper beds of the Carboniferous system consist of thick red sandstones, which are well developed at East Wemyss. These rocks are here, as the name of the place indicates, pierced by numerous caves hollowed out by the action of the sea. These are not so extensive as those of the Arbroath coast, nor does the sea reach them now, for they form part of a Raised-beach. These red sandstones are perhaps the youngest rocks in Fifeshire, for mesozoic strata are entirely absent. If they ever existed, they have long since been removed by denudation.

It only remains to mention the Boulder-clay, which attains in places a thickness of 90 feet, and the Post-tertiary beds with glacial shells, exposed at low water on various parts of the coast. During the Ice age the physical conditions all over Scotland were so uniform that these deposits offer no features of special interest.

Sub-aërial accumulations are represented by the sand dunes along the southern shores of the Tay and by the golf-links of Leven, Largo, and St. Andrews. There is a good example of a Raised-beach above the pier at Aberdour, where marine shells of existing species occur in beds at a level quite 40 feet above the present high-water mark.

In the west of Fife the old coast-line can be traced in some places fully a mile inland from the present beach, and here and there a second or intermediate coast-line can be made out. At Kincardine 360 acres have been reclaimed from the river by means of a sea-wall constructed after the Dutch fashion. Between this town and Stirling the numerous windings of the Forth and the

alluvial flats on either bank furnish convincing proofs of the power of a river to restore a depressed level. Many years ago the skeleton of a whale 70 feet in length was discovered north of Stirling at Airthrey, near the northern limit of the alluvium, at a level 22 feet above the highest spring tides of the present day; and the remains of seals have been dug out of the brick-clays of Strath Eden. The evidences of recent depression are not so obvious in Fife as those of elevation, but submerged forests are stated to occur on the coast near Largo and in the Tay. There are a number of dried-up lakes throughout Fife, one of which is situated to the north of Aberdour. In constructing the railway between the Forth Bridge and Inverkeithing, after tunnelling the whinstone, a small ravine had to be crossed. The embankment thrown over this space kept sinking for months, the adjoining high road was pressed up 25 feet above its former level, and a neighbouring field was converted into a series of hillocks by the displacement of the subsoil, which apparently consisted of fine laminated clay.

On the shore at Port Laing, which is in the immediate vicinity, some years ago two ancient canoes were discovered, and on the hillside near North Cliff a Roman road can still be traced. In the museum of the Society of Antiquaries, Edinburgh, may be seen a pair of Celtic urns found at Craig Dhu, North Queensferry, in 1859; and quite recently a series of similar urns were unearthed at Pitreavie, south from Dunfermline. Rough and polished stone hatchets have occasionally been picked up in the same neighbourhood.

Marvellous is the story furnished by these stony records of the past, marvellous what they tell, more marvellous what they leave untold, of long protracted ages and innumerable forms of life that have come and gone, leaving behind them no memorial of their existence. Neither the pterodactyl nor the deinosaur have left their footprints on the shores of Fife, for this reason, that of all the natural phenomena which occur in any locality, while some are duly recorded in earth's rock-leaved annals, others unchronicled, as in the case of that long geological drama of mesozoic times, are destined to dissolve,

> "And, like this unsubstantial pageant faded,
> Leave not a wrack behind."

No. XXXV.—Notes on a Visit to the Culbin Sands, Morayshire. By James Barclay Murdoch, *Hon. Sec.* With a Map. [Plate, No. XVI.]

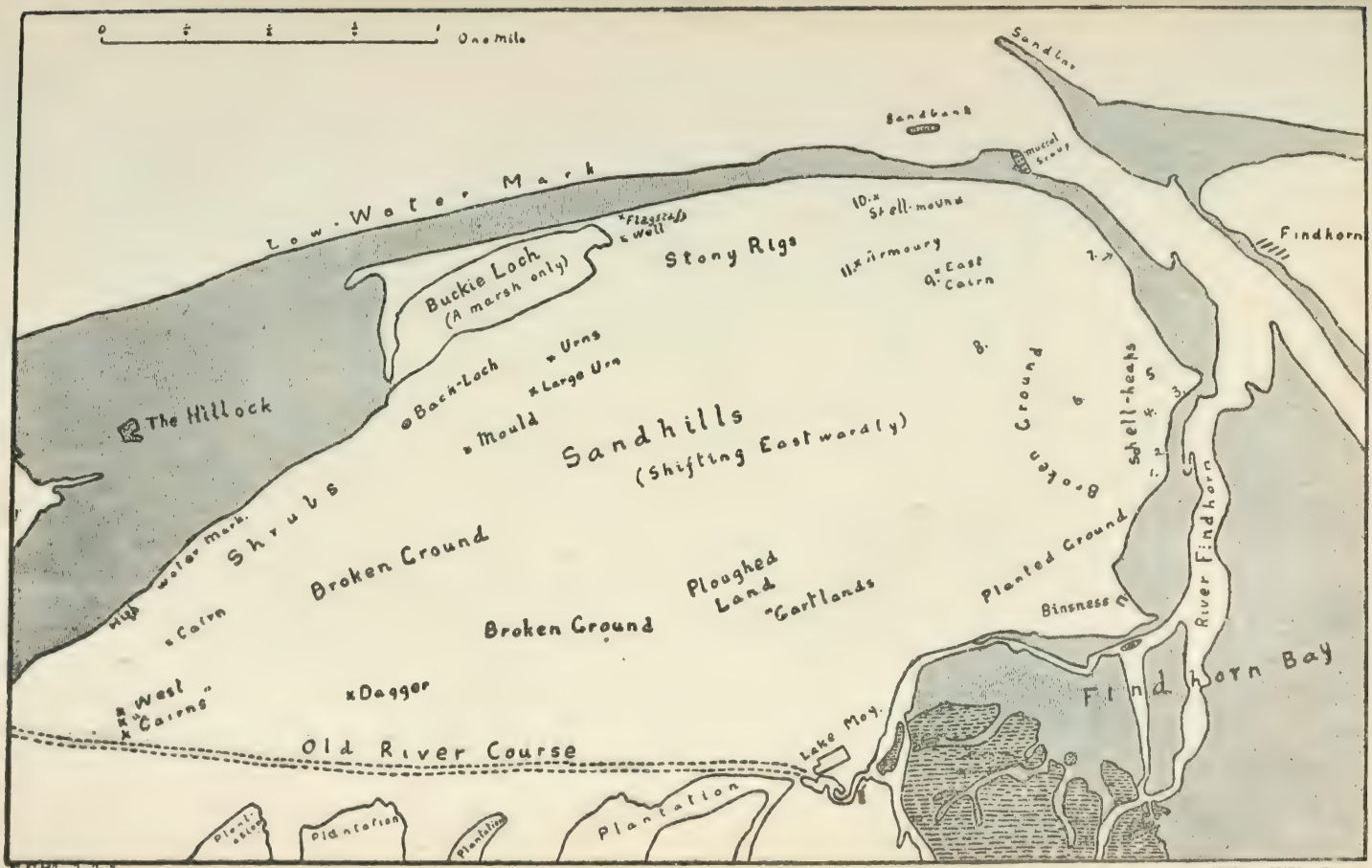
[Read 16th January, 1891.]

(Abridged.)

On two occasions in the months of July and August, 1890, I carried out a long-deferred intention of visiting the northern counties of Banff and Elgin (or Moray). Amongst other places I saw Portsoy, Elgin, Lossiemouth, Grantown and Speyside, and Forres, with the Valley of the Findhorn. Whilst at the last-mentioned town I spent some time amongst the sandhills of Culbin, which skirt the coast-line between Findhorn and Nairn. Days might have been spent profitably and agreeably at Portsoy, with its serpentine and graphic granite, or at Elgin, with its sandstones and reptilian remains of much disputed age and succession; but the bare and arid wastes of "Coobin" had for me a surpassing interest, both geological and archæological, and I purpose, therefore, on the present occasion, to confine my remarks to some of the salient features of that district.

Unlike our own Ayrshire sandhills, so well described by Mr. John Smith (*Transactions*, vol. vi., part 2, p. 185), these northern sand accumulations remain much as they have been for generations, for there is no extent of population or industrial occupation near them, and, with the exception of some small amount of tree-planting on their inland border, no attempt has yet been made to curb their shifting and erratic formation. Perhaps nowhere better in Scotland can the observer have an opportunity of noting the unfettered action of wind-blown sand than in this Morayshire desert.

Great geological interest attaches to such sand-action as bearing upon the origin and formation of sandstones of various ages. Green, in his "Geology," 1880, p. 149, says, "Another very common form of terrestrial accumulations is that of Blown Sand. . . . These often show, when cut into, rude bedding, and the action of the wind produces in them structures exactly analogous to the current-bedding and ripple-drift of subaqueous sandstones. In some cases the sand is mixed with broken shells, and water percolating through the mass dissolves out the carbonate of lime and



G.F. Black, del.

CARTER & PRATT, LITH.

SKETCH MAP OF CULBIN SANDS, MORAYSHIRE.

re-deposits it as a cement, so that a hard calcareous sandstone is produced. . . . It is therefore possible that some of the sandstones of the earth's crust may have been originally Blown Sand."

And Beete Jukes, in his "Students' Manual," 1862, p. 154, under the title "Aërial Rocks," after describing many instances of such deposits, quotes De la Bêche, that on the coast of Cornwall the sand, composed largely of fragments of shells and corals, sometimes becomes converted by carbonate of lime or oxide of iron into a hard stone.

The total area known as the Culbin Sands has been stated to be about 10 miles long by 3 broad, or an area, roughly speaking, of about 4000 acres. The largest consecutive stretch of the sandhills is, however, about 4 miles by 2, and its shifting covering varies from almost nothing to nearly 120 feet, a height reached by some of the larger hills. One of these, lately measured, had a base area of 440 yards by 220, its longest axis being east and west, like those of the other hills. Taking the above lesser area with its heights and hollows, a young engineering friend has calculated for me that the accumulation of sand upon it represents a weight of something like 50,000,000 tons.

The surface and position of all this vast body of silicious particles is changing from day to day and from hour to hour at a rate which of course varies greatly, being dependent on the force, direction, and velocity of the wind. It is said that in this district the wind blows from a westerly direction three days out of four, and in stormy dry weather a very short time suffices to materially alter the sandhills with their corresponding valleys. At the time the Ordnance Survey was made, the greatest elevation was found to be 99 feet, while at present it is considerably over 100 feet.

A noticeable feature in the formation of sandhills is the great difference between the gradients of their sloping sides, the leeward sides having at least double that of the windward ones. At Culbin, as already remarked, the western side is the windward one, the wind from that "airt" averaging more than double that from all other quarters.

To any one who has traversed the sand wastes of our western and northern coasts, the wind-formed ripple-marks are a very marked characteristic; they are quite as frequently formed in this

way as by the action of water on a sandy shore. In certain sandstone strata such ripple-marks are as plain as if they had been formed to-day. And in some of their hollows may be traced layers of different coloured, perhaps lighter, material, just as we see in recent examples.

Certain darker coloured bands and layers of stratification, seen on the surfaces of some of the sand slopes at Culbin, seemed to form remarkable patterns, which brought vividly to one's mind the wavy band lines on "watered" silk. These I have seen also on some of the Irish sandhills, and from appearances on some of our sandstones they must have been similarly formed in geological times.

When the encroachment of the blown sand on the cultivated fields and pasture lands of Culbin first began is not known to history, but there are in existence various notices recording successive disasters which came with storm and flood. Buchanan, in his "History of Scotland," states that about A.D. 1000 there was an inroad of the sea which not only overflowed the fields and covered them with sand, but swept away many houses. Boethius, another historian, mentions that at the time of the formation of the Goodwin Sands (*i.e.*, about A.D. 1100) the sea desolated part of Moray and destroyed the fields with sand.

But not till about the year 1650 do we find wind-blown sand spoken of. Then it appears to have reached the grass lands lying inside and along the Raised-beach terraces which lined the coast. Year by year afterwards it overran these grassy reaches till, in 1676, it reached the grain fields. On 17th July, 1695, Alexander Kinnaird, the then proprietor of Culbin, petitioned Parliament to be exempt from cess tax, "because his estate, which, twenty years previously, was one of the most considerable in Moray, was nearly all covered with sand, and the mansion-house and orchard destroyed." Two years later he again applied for a personal protection from his creditors, on the ground that three-fourths of his estate were overrun with sand, and the remaining fourth part had already been sold for their benefit.

Culbin appears to have at one time carried a considerable population. There were a number of small farms, besides the Home farm, and many crofts occupied by fishermen, just such a state of matters as exists on many parts of the coast at the present

day. There was a church on the ground, the site of which is still known as the Chapelhill. The local belief is that the estate, with its mansion house and many of the cottages were blotted out of existence by the sand blast on one awful night of storm. More probably, as previous statements shew, that was not the case, but that after a struggle for years against the advancing wave, one tempestuous night completed the half-finished destruction of houses and fields.

About the beginning of this century a tremendous gale which raged for several days shifted the sandhills to such an extent that buildings were exposed to view, including the old mansion. And it is said that so long as it re-appeared it formed a convenient quarry for the house-builders of the district, who treated it in the same ruthless manner that has worked woe to our old castles. A later storm again hid its remains from the spoiler, and it still remains buried in its sandy covering.

Previous to these days of misfortune the estate of Culbin, with the adjoining properties, formed part of the rich and fertile tract of country which was known as the granary or "girnel" of Moray, from the richness and earliness of its crops, a character which the existing arable lands still maintain. No doubt this long-continued fertility is due largely to the fact that the great alluvial tract which borders the sea for many miles, along the southern shore of the Moray Firth, is the long-accumulated result of combined river and sea action, and has had stored up in it all the constituents of plant life.

Seawards of the sandhill area, and along the shore of Findhorn bay, lie stretches of Raised-beaches which were formed previous to the last rise of the land; they are known in the district as "stony riggs," consisting largely of water-worn pebbles of various sizes. Again bordering on, and inland from, these are low terraces covered with dark sandy soil, and carrying on their surface many shell-mounds of all dimensions.

In the latest edition of Shaw's "History of Moray," 1882, the editor states that "the relics obtained from the old lands of Culbin belong to a period too close at hand to be of much interest to the antiquary." But this is a grave misstatement, for the portions of ground just described, alternately covered with, and bared of sand, have of late years yielded a rich harvest to the antiquarian, and

the Edinburgh Museum of the Society of Antiquaries of Scotland has received from this locality many thousands of flint and stone implements, including arrowheads, knives, scrapers, axes, hammer stones, whorls, querns, &c., besides numberless articles of pottery, bone, bronze, and iron.

Such remains of the old inhabitants bear evidence, as well as that afforded by the shell-mounds, to the long-continued prehistoric occupation of the district. These enormous accumulations of shells, often called "kitchen middens," are largely composed of the shells of edible molluscs, such as the oyster, cockle, mussel, whelk, limpet, and periwinkle. The oyster is said to be now altogether or almost extinct in the Moray Firth, and if such is the case there must have been a great change from the old conditions under which it flourished. It thrives on muddy flats but is killed by sand, and the presence of its shells in abundance in the old shell-mounds, and its subsequent disappearance as a living animal, emphasize the evidence afforded by the sand invasion of the cultivated and pastoral lands.

And whence has come this influx of sand? There have doubtless been considerable alterations of shore-line along this part of the coast, even in comparatively recent times, and the sea has attacked and removed a large amount of previously existing shore deposits. Great waste by denudation of the upper strata of the surrounding districts must have been going on for ages, and the Moray Firth itself is a huge slice carved out of the Old Red Sandstone, which still lines both its northern and southern shores. The strong and rapid currents of the Spey, the Findhorn, the Ness, the Beauly, the Conon, and the waters which empty themselves into the Cromarty Firth, not to speak of the smaller streams, are constantly carrying down to the sea burdens of sand derived from the strata through which they pass. Some of these rivers, and notably the Findhorn, are prone to extraordinary and sudden floods, which, bringing down from the higher grounds quantities of debris, subject the rocky banks to enormous wear and tear.

As regards the Findhorn, its action as regards the sand is something like the following. Discharging itself into a land-locked arm of the sea, known as the Bay of Findhorn, which has an area of about 1000 acres, the sands it bears are first carried down to the open sea, then borne by the tides and currents westwards for a

certain distance, till they are thrown up all along the southern coast of the Moray Firth towards Nairn. Then, coming under the influence of the prevailing westerly winds, the sand is blown into Culbin, which retains it for a longer or shorter period till it eventually finds its way to the western side of Findhorn Bay, and back into the river channels, through which it travels seawards, again to repeat its endless round.

But for this watery barrier, which it never crosses except in times of high storm, the travelling sand would have desolated much of the land lying to the east of Findhorn Bay. Indeed, we know that at least on one occasion the sand did manage to pass over, invading the fertile parishes of Kinloss, Duffus, and Alves, where its remains, in the shape of grass-covered mounds, are still to be seen, though much of the more slightly covered ground has been reclaimed by having the old soil trenched up above the sand.

It should be stated that the whole area of Findhorn Bay has now become filled with sand which is dry at low water, with the exception of the two river channels. That of the river Findhorn is now some miles eastward of its old course, a change probably gradually induced by the action of the flowing sand.

On the inland edges of the sandhills, plantations of Scotch firs have of late years been made, with the intention, which seems to have been fairly successful, of arresting the southern influx of the sand. Most of the trees I saw were thriving, though in some places more or less buried, and I heard that in one plantation the sand had quite overtopped them.

In some of the flat bottoms at the foot of the sandhills the old surface black soil was laid perfectly bare, with the rigs of the ancient cultivation distinctly visible. Numbers of water-worn pebbles and angular fragments of stone were lying scattered over it, and all of these, except a few of soft formation, shewed the most wonderful polish from the continual sand blast. Though the old soil seems to have been buried for at least 200 years, it still retains the dormant seeds of vegetation, and, when freed from sand for one year, begins to throw up a strong plant growth. In February, 1817, the late Sir Thomas Dick Lauder caused a couple of flower-pot saucers to be filled with a sample, and in the following May he found that a tender growth of no less than 46 plants of 4 species had sprung up in them. These he

identified as Mouse Ear (*Cerastium arvense*), Scorpion Grass (*Myosotis scorpioides*), Purple Archangel (*Lamium purpureum*), and Corn Spurry (*Spergula arvensis*), all of them being plants which we know as "field weeds."

I have found that the best time to visit Culbin, or similar localities, is on a fine morning after rain, as then the surface of the sand is moist, and the usually moving grains of silica are quiescent. When there is a breeze, however light, unless the surface is damp, the untiring oncome of the sand soon becomes unpleasant, while in high wind it is decidedly disagreeable, if not dangerous.

One day I drove from Forres to Culbin, past Kingcorth, was such an ideal occasion—the bright blue sky and the gentle breeze had come after a wet night, and the sand surface was moist and firm, affording good footing everywhere. The slopes exposed to the sun were beginning to dry in patches. Soon we reached the top of one of the highest hills, and how splendid was the outlook! In the foreground sandhill after sandhill, hollow beyond hollow. Then the bright sparkle of the Moray Firth, with the receding coast line of Ross and Cromarty fading into the northern distance, and the Dunrobin cliffs with some of the more distant hills showing clear against the sky-line. Long we looked, and map in hand, puzzled out each point in this classic ground.

From this we descended into one of the intervening valleys, where all traces of the world were shut out, and except the sky above, sand, and sand alone, met the eye. Life, animal or vegetable, was entirely absent. Winding along through the branching hollows, we at last reached the southern edge of the sand drift, but it was easy to realize that in storm or darkness it would be almost impossible to find one's way.

Of the locality during such times I had no experience, but all accounts agree in saying that it would be foolhardy to try to cross Culbin on either occasion. The editor of Shaw's "Moray," 1882, already referred to, seems to have had an exciting time in an attempt to cross it during a storm, but his account is too long for quotation, and reference may therefore be made to the work itself.

It is only after stormy weather, when the sand has somewhat shifted, and before the relic-hunters are abroad, that prehistoric

remains are likely to be met with, so I did not meet with any. I crammed my pockets with the polished pebbles, which glistened brightly in the sun, and at a miniature waterfall (of sand), which, from the influence of the breeze above, was falling over a steep bank, I filled my handkerchief with the flowing silicious grains which were of the finest and most uniform quality. As to the latter, I afterwards found I need not have taken any trouble, for, on my return to Forres, I discovered, that slight as the breeze had been, it had loaded every pocket, every fold of dress and umbrella, with so much fine sand, that I had unconsciously brought away with me nearly as much as the amount of my gathered sample.

[A fully illustrated "Report on the Archæological Examination of the Culbin Sands," by Mr. George F. Black, which was read before the Antiquarian Society of Scotland, on May 11, 1891, has been published in the Society's volume of Proceedings for 1890-91, and will well repay perusal. By the courtesy of the Council of that body I have been enabled to append to my paper a reduced copy of the Sketch Map drawn by Mr. Black to accompany his paper, and for the use of which I have to return my best thanks.—J. B. M., *Jan.* 1893].

PROCEEDINGS FOR SESSION 1890-91.

(33rd Session.)

Society's Rooms, 207 Bath Street, 9th October, 1890.

Mr. Dugald Bell, *Vice-President*, in the Chair.

Mr. William Scott, 3 M'Aslin Street, Glasgow, was elected an Ordinary Member.

The Chairman welcomed the Members on their assembling to open a new Session, and hoped that all would contribute to make it a useful and interesting one.

Mr. D. C. Glen, F.G.S., the Society's delegate to the recent meeting of the British Association at Leeds, gave an account of the more interesting geological papers and excursions there.

Mr. James White, *Hon. Librarian*, read a paper entitled "Notes on Lewis, with Chips of the Rocks." In it he summarised the writings of the various authors who had discussed the geology of the island, and then gave his own views regarding the stratigraphical position of the rocks, their glaciation, and the distribution of boulders.

At its close some remarks were made by Mr. William Jolly, F.G.S.; Mr. John Young, F.G.S.; and the Chairman (Mr. Bell).

Society's Rooms, 207 Bath Street, 13th November, 1890.

(Annual General Business Meeting.)

Mr. Joseph Sommerville, *Vice-President*, in the Chair.

The Hon. Secretary (Mr. Murdoch) read as follows:—Report of the Council for the year ending 30th September, 1890. [See page 434.] The *Hon. Treasurer* (Mr. John Wight, C.A.), submitted his financial statement for 1889-90. [For Abstract of Accounts, see page 442.] The *Hon. Librarian* (Mr. James White) read his report upon the business of the Library for the year ending 30th September, 1890.

After some remarks by Mr. Dugald Bell, Mr. R. J. Steele, and other members, the adoption of the reports was unanimously agreed to.

The Rev. Mr. Mackintosh then proposed a hearty vote of thanks to the Honorary Secretaries (Mr. James B. Murdoch and Mr. Gavin M. Pratt), to the Honorary Librarian (Mr. James White), and to the Honorary Treasurer (Mr. John Wight, C.A.), for their work in the interests of the Society. The motion was seconded by Mr. John Young, F.G.S., and cordially agreed to.

The election of office-bearers was next proceeded with, and the undernoted members were declared to be duly elected to fill the vacancies in the Council for a term of three years:—President, Sir William Thomson, F.R.S.; Vice-President, Mr. William Jolly, F.G.S.; Members of Council, Messrs. Dugald Bell, James Clark, Robert Dunlop, John Renwick, and Dr. S. Sloan; Auditors, Messrs. David Pearson and James Steel; Hon. Secretary, Mr. James B. Murdoch, F.R.Ph.S.E.; Assistant Hon. Secretary, Mr. Gavin M. Pratt; Hon. Treasurer, Mr. John Wight, C.A.; Hon. Librarian, Mr. James White.

The following gentlemen were elected Ordinary Members:—Messrs. Alexander Birrell, 227 West George Street; Robert Brownlie, 8 Ardgowan Terrace, Sandyford; W. B. Hair, 226 West Regent Street; and William M'Ewan, 148 Bothwell Street.

Mr. John Howat exhibited, with remarks, a number of fine specimens of Double Termination Quartz Crystals of great brilliancy from Little Falls, New York State, U.S.; also a series of Silurian Fossils from the same locality.

Mr. John Young, F.G.S., *V.P.*, exhibited specimens and sections of an ultra-basic crystalline rock of igneous origin, belonging to the Peridotite group, which were taken from the spoil-heap at the southern end of the new tunnel of the Glasgow Corporation Water-works, which passes through Mugdock Hill, Milngavie. He said that Peridotite seems to be eruptive amongst the older igneous rocks of the Mugdock district, and that it belongs to a class of rocks noted for their high specific gravity and for their bearing evidences of having been thrown up from deeper sources than those from which the associated igneous rocks were derived. In the present specimens the olivine crystals are seen to be moderately large and fairly numerous, appearing to have suffered little alteration in their colour and composition. They are imbedded in a matrix of basic felspar, with magnetite and titanic iron in grains. Specimens of a similar rock from Langbank, on the Clyde, show a great alteration of the olivine crystals, their colour having been changed from its normal olive green into a deep red, which was due to the oxidisation of the iron present in their composition. Such ultra-basic rocks as the Peridotites are rare in most parts of the world, but seem to have been erupted at several points in the trappean hills round Glasgow. They are interesting to petrologists from the fact that their mineral composition approaches closely to that of some of the meteoric bodies which have reached our earth from space.

Remarks on the subject were also made by Messrs. Dugald Bell, David Ross, LL.D., and the Chairman.

Society's Rooms, 207 Bath Street, 11th December, 1890.

Mr. John Young, F.G.S., *Vice-President*, in the Chair.

Mr. Ronald M. Johnstone, C.E., 75 West Nile Street, and Mr. James Reid, 26 Westmuir, Parkhead, were elected Ordinary Members.

The Chairman called attention to the honour which had been conferred upon the President of the Society, Sir William Thomson, in his recent election to the Presidentship of the Royal Society, a distinction which had not, he believed, been conferred previously upon any member of that learned body who was not resident in London. Mr. D. Bell proposed and Mr. D. C. Glen, F.G.S., seconded a motion that the Hon. Secretary be instructed to congratulate the President, on behalf of the members, on his appointment to the highest scientific post in Great Britain.

Mr. Robert Dunlop exhibited, from the cabinet of Mr. Jack, Airdrie, a specimen of a fossil spider, *Palæophalangium Scoticum*, from the Carboniferous shale overlying the Kiltongue coal near Baillieston; also several beautiful drawings of this new form on an enlarged scale, by Mr. B. M. Peach, of H.M. Geological Survey, who had undertaken to describe it for the Society's *Transactions*. Mr. Dunlop said that it used to be commonly believed that Carboniferous vegetation was devoid of animal life, but through the labours of Mr. James Bennie, of the Geological Survey (a member of this Society), and other workers, such an idea was now quite exploded. If collectors of ferns and other Carboniferous plants would keep their eyes open when searching the shale-heaps many new forms would doubtless yet be discovered.

The Chairman (Mr. Young) exhibited under the Society's microscope sections of Peridotite, an ultra-basic igneous rock, which he had prepared from a small chip received from Mr. John Smith, Kilwinning, stating that he exhibited them in illustration of the changes which had taken place in their constituent olivine through weathering or whilst lying in the earth's crust. At last meeting of the Society he had exhibited specimens of Peridotite from the Mugdock Tunnel, near Milngavie, in which the olivine crystals were little altered from their normal olive-green colour. In the specimen from Kilwinning the alteration of the olivine by oxidation of the iron is seen to have been completed in all the smaller crystals, while in the larger ones the change has not advanced far beyond the outer margins, the colour showing an outer border varying from red to orange-red and yellow. These surround the less altered portion of the olivine, which is now of a pale bluish-green colour, and in which is developed a new crystallisation consisting of a finely fibrous stellate structure, like that seen in delessite. Zonal bands of silica or an allied mineral surround many of the crystals, and the rock under its altered condition forms a most beautiful and interesting object for microscopic investigation.

Mr. D. C. Glen, F.G.S., exhibited cores of the various Carboniferous rocks which had been passed through during the progress of a bore at present being put down at Wellpark Brewery.

Mr. James White showed an *Echinus* spine, *Cidaris grandiferus*, of a curious fruit-like form, found in Cretaceous rock in the Holy Land.

Mr. James S. M'Lennan read a paper entitled "The Geology of Kyle" [see page 264], which was illustrated by the Geological Survey maps of the district. At its close an animated discussion was taken part in by several members.

Society's Rooms, 207 Bath Street, 16th January, 1891.

Mr. William Jolly, F.G.S., *Vice-President*, in the Chair.

Mr. Arthur Pollock, Manager, Dillichip Works, Bonhill, was elected an Ordinary Member.

Mr. Joseph Sommerville called attention to the death of a distinguished Honorary Associate of the Society, Mr. James Croll, LL.D., and paid a feeling tribute to the memory of the deceased gentleman. The Chairman said the members of the Society owed it as a duty to themselves, and to the memory of the deceased member, to adopt such a motion as that shadowed forth by Mr. Sommerville. Dr. Croll had done much special and original work which was not yet fully recognised and acknowledged as it ought to be by the world of science. Mr. John Young, F.G.S., corroborated the Chairman's remarks and spoke of Dr. Croll's early association with Glasgow, and his first connection with the Society. The Chairman then moved, and Mr. Dugald Bell seconded, a motion that an expression of deep regret at the decease of Dr. Croll should be recorded in the Society's minutes, from which an extract should be forwarded to Mrs. Croll.

Mr. John Howat exhibited specimens of Cornish Granite and Kaolin (China clay) resulting from its decomposition, the latter product being largely imported to Glasgow and elsewhere for the manufacture of china-ware.

Mr. James B. Murdoch, F.R.Ph.S.E., *Hon. Secretary*, read a paper entitled "Notes on a Visit to the Culbin Sands, Morayshire" [see page 406], which was illustrated by a map of the district and by various specimens. At its close, a discussion was taken part in by the Chairman (Mr. Jolly), Mr. John Young, F.G.S., Mr. Joseph Sommerville, Mr. Dugald Bell, Dr. Sloan, and other members.

Society's Rooms, 257 Bath Street, 12th February, 1891.

Mr. John Young, F.G.S., *Vice-President*, in the Chair.

The death of Mr. Robert Mason, F.L.S., long a member and office-bearer of the Society, was referred to by the Chairman, and remarks were also made by several other members. It was unanimously agreed that an expression of regret at Mr. Mason's death should be entered in the minutes.

Mr. David Stirling, coalmaster, Kilsyth, was elected an Ordinary Member.

Mr. Dugald Bell exhibited specimens of Labradorite from Newfoundland. It is a triclinic felspar, and is especially a constituent of the augitic rocks, such as dolerite, basalt, hypersthenite, &c.

Mr. John Renwick exhibited a specimen of Crocidolite from Orange River, South Africa.

Mr. Robert Dunlop exhibited specimens of Barium Sulphide and of Lead Crystals from Leadhills, South Lanarkshire, and made some remarks upon their occurrence and composition.

The Chairman (Mr. Young) read a paper "Notes on the Group of Carboniferous Ostracoda found in the strata of Western Scotland, with a Revised List of Genera and Species" [see page 301], which was illustrated by a large number of mounted specimens, shewn under the Society's microscope.

The Hon. Secretary (Mr. Murdoch) read, on behalf of Mr. John Smith, Kilwinning, a paper upon "Peculiar U-shaped Tubes in Sandstone, near Crawfurdland Castle, and in Gowkha Quarry, near Kilwinning." [See page 289].

Society's Rooms, 207 Bath Street, 12th March, 1891.

Mr. Joseph Sommerville, *Vice-President*, in the Chair.

Mr. John Young, F.G.S., *V.P.*, exhibited (1) a specimen of Carboniferous Sandstone, containing one of the curious U-shaped burrows described by Mr. John Smith in his paper read at the previous meeting, and supposed to have been the home of a sand-boring annelid or crustacean [see page 289]. Mr. Young shewed (2) a large slab of Carboniferous Shale from one of the roof coals of a pit at Mount Vernon, which contained two beautifully-preserved impressions of the fronds of a Fossil Fern, *Alethopteris lonchitica*, a characteristic species of the Scottish Upper Coal Measures. Mr. Young exhibited (3) a specimen of Anthracitic Coal from the recent excavations at the base of the Necropolis hill for the Wellpark Brewery Co. This coal has been rendered columnar through partial fusion from contact with heated igneous rock (dolerite). The columns are polygonal, and about half-an-inch in diameter. All the above specimens had been presented to the Hunterian Museum, the first by Mr. John Smith, the others by Mr. Thomas Naismith.

Mr. James B. Murdoch, *Hon. Secretary*, exhibited two specimens of Fused Rock, one shewing columnar structure, from the Vitrified Fort on one of the Burnt Islands, Kyles of Bute, and made some remarks upon the origin and structure of these interesting prehistoric remains. He stated that Hugh Miller, in his "Rambles of a Geologist," appended to his delightful "Cruise of the Betsy," had well summarized the theories formed by previous writers:—(1) That of Pennant, who supposed Vitrified Forts to be volcanic in their origin, and simply the outer rims of extinct volcanoes! (2) That of Williams, one of our earlier British geologists, who held that

they were designedly vitrified in order to cement into solid masses their loosely formed walls. (3) That of Lord Woodhouselee, the historian, who thought the stone walls had been merely the foundations of higher wooden structures, and that their vitrification had accidentally happened when the upper buildings were destroyed by fire. (4) The view of Sir George Mackenzie, who believed that the fusing of the stones proceeded from beacon fires, kindled to warn the neighbouring inhabitants of the presence of a foe.

Hugh Miller himself inclined to the second theory, that the walls were purposely vitrified, though afterwards they may, from their situation in many instances, have been used as the sites of beacon fires. Mr. Murdoch said that so far as he had seen such forts there seemed to be little room for doubt that the fusing of the stones composing the walls was designed to weld the roughly-built materials into a solid mass, both for defensive purposes and to resist the action of the weather. The vitrification is much too regular to be the result of accident. It was probably induced by the action of an alkali—in inland situations, from wood ashes—in such a locality as the one from which the present specimens came, from sea-weed. Had the walls at the Burnt Islands been untouched Mr. Murdoch would not, he said, have been the one to disturb them, but they were, he was sorry to say, not much more now than upturned confused masses, with many detached portions lying in all directions. Whether treasure-seekers, rabbit-hunters, or mere mischief-makers, had been guilty of this vandalism there is no record to shew. There were still many existent examples of these interesting structures to be met with in the Clyde district and elsewhere, but it was not his purpose at the present time to do more than allude to them in connection with the theory of vitrification.

Mr. Murdoch then read, on behalf of Mr. John Smith, Kilwinning, a paper on "The Ardrossan Shell Mound, with an account of its Excavation" [see page 355]. This mound was thoroughly investigated by the author some years ago where it lay, at the Rock Shelter, close to the Ardrossan station of the Glasgow and South-Western Railway.

The paper was illustrated by sections and plans, and by a large series of bones of animals and shells of mollusca found in the mound.

Some remarks on the subject were made at the close by various members.

Society's Rooms, 207 Bath Street, 9th April, 1891.

Mr. John Young, F.G.S., *Vice-President*, in the Chair.

Mr. Joseph Sommerville exhibited specimens of Garnierite, a Silicate of Nickel, found in Serpentine, in New Caledonia, and imported for commercial purposes, there being a considerable demand for the metal. He remarked that this mineral, named after its discoverer, Garnier, was first found in the Island of Noumea, but has since been met with in Australia and in some parts of North America.

Mr. D. C. Glen, F.G.S., also exhibited a number of specimens of Nickel ore in the rough state, and of the crude and the pure metal.

Mr. Joseph Sommerville exhibited a simple form of Specific Gravity Balance for testing rocks and minerals, and showed its practical working.

The Chairman (Mr. Young, read a paper entitled "Notes on a small Group of Carboniferous Foraminifera found in the Lower Limestone Shales of the Muirkirk district in Ayrshire, with a list of the Genera and Species found in the Coalfields of Western Scotland" [see page 313], in which he stated that these minute organisms existed in a finer state of preservation and in greater numbers in the rocks of the Muirkirk district than in any district of Western Scotland where they had yet been found. To show their minute forms and structure he exhibited, under the Society's microscope, a series of transparent sections prepared by himself, in which were seen several new and undescribed species. The group has been studied by Dr. Carpenter, by Professor T. Rupert Jones, and by Dr. Brady, the latter having published a monograph on it; but doubtless many new forms yet remain to reward the diligent observer, and here, Mr. Young observed, there is a good field for some of the younger members of the Society to work up.

Mr. Robert Dunlop read "Note on a 'Wash out' in a Shallow Pit of the Drumshangie Coal Company, near Airdrie." [See page 320.]

Society's Rooms, 207 Bath Street, 7th May, 1891.

Mr. William Jolly, F.G.S., *Vice-President*, in the Chair.

Mr. John Young, F.G.S., exhibited, on behalf of Mr. D. C. Glen, F.G.S., who was unable to be present, a selection of Minerals, Polished Gems, and Cut Stones, from the portion of his magnificent collection which had been lent to the East End Exhibition, Dennistoun, and from which it had just been returned. The selection comprised many and fine examples of Chalcedony, some with dendritic markings; Agate in the ringed forms of Onyx and Sardonyx; Cameo, Egyptian Jasper, Crocidolite, Silicate of Copper; and numerous other rare and precious specimens. Mr. Young described a number of the more notable examples, and stated that, growing from a very small nucleus formed about the commencement of the Society's foundation [1858], Mr. Glen's collection had now become unrivalled amongst private collections in the West of Scotland, if not in a wider area. He regretted much, in common with many others, that so far as exhibited, it had not been displayed to greater advantage in the late Exhibition, of which it ought certainly to have formed one of the most attractive features. The fact was, however, it had been so carefully bestowed in one of the lower and most inaccessible rooms, that visitors in general were unaware of its existence.

The Chairman (Mr. Jolly) remarked that he had never before met with such a private collection, and regretted that its value for educative purposes had not been sufficiently realized by the late Exhibition committee. Mr. Ruskin, one of whose most fascinating works, "Deucalion," was largely devoted to the study of Chalcedonies and Agates, had given

his wonderful collection of these minerals to the nation, and any of the members who had the chance of being in Sheffield should not omit to see it at its permanent home in that town.

Mr. Robert Dunlop exhibited a small collection of Fossil Fish. One of the specimens shewed a curious forgery, the head of one species being deftly attached to the body of another, as was first pointed out by Dr. R. H. Traquair of the Science and Art Museum, Edinburgh. Such manufactured specimens of fossil organisms are by no means unknown, as they are got up by unscrupulous dealers for the purpose of being palmed off upon young or inexperienced collectors.

The Hon. Secretary (Mr. Murdoch) read, on behalf of Mr. James Bennie, of H.M. Geological Survey, a paper entitled "Scenes and Sections in Thornton Quarries, East Kilbride, in 1868." [See page 276]. After describing his various visits to Thornton, and explorations of its fossil-bearing strata, Mr. Bennie said that his more special purpose was to point out to the younger generation of collectors the opportunities still offered in this locality for further examination and discovery.

A short discussion on various subjects brought up in the paper was taken part in by several members.

The Chairman, before closing the meeting, spoke of the issue of part i., vol. ix., of the Society's *Transactions*, and said that from a cursory examination it appeared to him to be one of the most valuable parts yet issued, and one likely to add to the Society's reputation for good and honest work. He concluded by proposing a hearty vote of thanks to the editor (Mr. Murdoch), which was unanimously agreed to.

Society's Rooms, 207 Bath Street, 28th May, 1891.

Mr. John Young, F.G.S., *Vice-President*, in the Chair.

Mr. Robert Starke, Solicitor, 43 West Regent Street, was elected an Ordinary Member.

Mr. William Jolly, F.G.S., *V.P.*, gave an account of an excursion lately taken by the members to Croy Hill and Barr Hill, on the line of the Roman Wall, near Kilsyth, and spoke of some of the more interesting geological features met with during the day's ramble.

Mr. James White, *Hon. Librarian*, exhibited specimens of several species of Carboniferous Plants belonging to the genus *Lepidodendron*, from shale, near Kilsyth, and made some remarks on their occurrence.

Mr. Mathew Blair exhibited specimens of Gold Ore from California, of Silver Ore from Nevada and Arizona, and of Silicated Fossil Wood from a buried river channel met with 200 feet below the surface in Nevada. He also made some remarks upon them, being followed by the Chairman (Mr. Young), and Mr. D. C. Glen, F.G.S.

Mr. Dugald Bell gave an abstract of a paper lately read by Mr. Percy F. Kendall, F.G.S., before the Literary and Philosophical Society of Manchester, upon the origin of certain boulders found in the Isle of Man.

Several of these of a fine-grained granite containing riebeckite, from the Isle of Man, and one from Moel Tryfaen, resemble in character the riebeckite rock of Ailsa Craig rather than that of Mynydd Mawr. Their occurrence confirms the conclusions arrived at from the evidence afforded by the striæ, that ice came out of the Firth of Clyde into the Irish Sea, and must have risen 250 feet between Ailsa Craig and Moel Tryfaen.

Mr. Dugald Bell then read a paper "On a Glacial Mound in Glen Fruin, Dumbartonshire," describing it as one of the most continuous and characteristic moraines which he had met with in the West of Scotland. [See page 345]. The paper was illustrated by sketches, maps, and photographs. An interesting discussion which followed was taken part in by various members.

PROCEEDINGS FOR SESSION 1891-92.

(34th Session.)

Society's Rooms, 207 Bath Street, 15th October, 1891.

Mr. Joseph Sommerville, *Vice-President*, in the Chair.

The Chairman congratulated the members on the opening of a new session, hoping that they had come back from their summer rambles in renewed health and spirits, and that many results in the shape of papers and specimens would be forthcoming at future meetings.

He then alluded to the death of one of the Society's oldest members—Mr. Walter Burns—who had been long an office-bearer and an occasional contributor to the *Transactions*. It was agreed that a note of his death should be recorded in the minutes, and that an expression of the regret of the members should be forwarded to Mrs. Burns.

A Concretionary Nodule of Carbonate of Lime, remarkably resembling an organic form, from schistose rock near Troon, was sent for exhibition by Mr. John Kirsop.

Mr. James White, *Hon. Librarian*, exhibited a number of Coral specimens from the Lias beds of Skye.

Mr. White then read a paper entitled "A Glimpse of the Irish Highlands," which was illustrated by numerous specimens of rocks and fossils.

Some discussion on the points raised by the author followed, and was taken part in by the Chairman (Mr. Sommerville), Mr. John Young, F.G.S., Mr. Dugald Bell, and other members.

Mr. D. C. Glen, F.G.S., then gave his Report as delegate to the recent (Cardiff) meeting of the British Association, which had been a very successful and enjoyable one.

SOCIETY'S ROOMS, 207 BATH STREET, 12TH NOVEMBER, 1891.

ANNUAL GENERAL BUSINESS MEETING.

Mr. WILLIAM JOLLY, F.G.S., *Vice-President*, in the Chair.

The HON. SECRETARY (Mr. Murdoch) read the Report of the Council upon the business of the past year. [See page 436].

The HON. TREASURER (Mr. John Wight, C.A.) read the Financial Statement. [For the Abstract of Accounts, see page 443].

The HON. LIBRARIAN (Mr. James White) submitted his Report on the work of the Library during the year.

A unanimous vote of thanks was then awarded to the Honorary Secretaries, Treasurer, and Librarian for their services in the work of the Society.

The election of office-bearers to fill the vacancies in the Council was then proceeded with, the following being the result :—

As Vice-President, Mr. John Smith, Kilwinning.

As Members of Council, Messrs. David Forsyth, Joseph Sommerville, D. C. Glen, F.G.S., James Steel, C. T. Dobbie, and John Dougan.

As Auditors, Messrs. David Pearson and John Main, F.G.S.

Mr. JAMES THOMSON, F.G.S., gave notice of motion that a sum of £8 should be devoted to the purchase of books for the Library.

A series of specimens of Phosphate of Lime in its nodular, earthy, compact, and crystalline forms, sent for exhibition by Mr. John Kirsop, was described by Mr. John Young, F.G.S., who stated that these varieties of the mineral vary considerably in the percentage of phosphate they contain, but that one and all, after being chemically treated, become the "superphosphates" of commerce, so generally known as powerful stimulants of vegetable life.

Prof. JOHN DOUGALL, M.D., St. Mungo's College, Corresponding Member, read a paper upon "The Leaf-caves of Mull" [see page 286], illustrated by a series of specimens from the Leaf-beds, which he had personally obtained from the rock *in situ*.

Mr. JOHN HOWAT also exhibited a small collection of Miocene plant remains which he had obtained in Mull a number of years ago.

Remarks upon various points touched on in the paper were made by Messrs. John Young, F.G.S., James Thomson, F.G.S., Joseph Sommerville, D. C. Glen, F.G.S., and the Chairman (Mr. Jolly).

SOCIETY'S ROOMS, 207 BATH STREET, 10TH DECEMBER, 1891.

Mr. JOHN SMITH, *Vice-President*, in the Chair.

The following gentlemen were elected Ordinary Members:—

Mr. James Rennie Barnett, Lilybank House, Johnstone.
Mr. John Carson, 6 Doune Quadrant, Kelvinside.
Mr. Charles Cowie, Merchant, Rangoon, Woodend, Partick.
Mr. William Hodge, 27 Montgomerie Drive, Kelvinside.

Mr. James Neilson, High Crosshill, Rutherglen.
Mr. John Grant Sharp, 127 Great Hamilton Street.
Mr. J. Parker Smith, M.P., Jordanhill, Partick.

The Hon. Secretary (Mr. Murdoch) read, on behalf of Dr. David Ross, a short notice of the late Mr. Daniel M'Millan, long a member and office-bearer of the Society, as follows:—

Last week there passed away, at the age of 64, Mr. Daniel M'Millan, a member of this Society, and formerly one of the vice-presidents. He was a keen lover of nature, and often took part in the excursions of this Society as well as those of the Archæological Society, of which he was also a member. Born in the Campbeltown district, he was early trained for the profession of teaching, in which he attained great success, being successively employed in the Training College, Edinburgh, as House-master in Neilson's Institution, Paisley, and as Head-master of Alexander's Endowed School, Glasgow. From the last position he retired only a few years ago. He resided for some years in Helensburgh, where he filled the office of Councillor with great acceptance. Of commanding presence, clear head, methodical habits, and fluent address, his services were much appreciated by the various educational societies in Scotland. Two years ago he was invited to become the President of the Educational Institute of Scotland; but failing health compelled him to decline that honourable but onerous position. He became a member of this Society in 1878, and was for a term of years a member of Council and Vice-president.

Mr. John Young, F.G.S., spoke of the recent death of another old member of the Society—Mr. James Dairon, F.G.S.—who had been an office-bearer for a number of years and an occasional contributor to the *Transactions*.

Mr. D. C Glen, F.G.S., spoke of his own recollection of the deceased members, and proposed that a vote of sympathy with the widow and surviving relatives of each should be passed, and an extract from the minutes forwarded by the Secretary. This was unanimously agreed to.

Mr. Joseph Sommerville exhibited a number of fine specimens of Rocks and Fossils from Canada, collected by himself during a recent visit, including Black Labradorite (Felspar), Nicolite, Asbestos, and Banded Agate. Mr. Sommerville also exhibited a collection of Photographs of Indian life.

The Chairman (Mr. John Smith), read a paper on "The Sand-hills of Torrs Warren, Wigtonshire." [See page 293.]

A discussion followed, being taken part in by Messrs. John Young, F.G.S., D. C. Glen, F.G.S., Dugald Bell, James Neilson, J. B. Murdoch, and other members.

Society's Rooms, 207 Bath Street, 14th January, 1892.

Mr. John Young, F.G.S., *Vice-President*, in the Chair.

In opening the meeting the Chairman expressed a hope that during the coming year Death would not be so busy amongst their ranks as he had

been during 1891, for since the end of last session the Society had lost no less than five of its more prominent members, the last to be taken away being the well-known and much-esteemed Archibald Robertson.

There had also lately been taken from us an honorary member, eminent in the geological world, Sir Andrew C. Ramsay, long known and esteemed as Director-General of the Geological Survey of Great Britain and Ireland.

The Hon. Secretary said that the Council had agreed that, subject to the approval of the members, a letter of congratulation to Sir William Thomson, President of the Society, on his accession to the peerage [under the title of Baron Kelvin], should be sent, and moved accordingly. The motion was unanimously agreed to.

A motion to devote £8 from the funds towards the purchase of books for the Library was made by Mr. James Thomson, F.G.S. Mr. John Wight, C.A., Hon. Treasurer, seconded, upon the condition that the expenditure should, if possible, be restricted to £5, and, with this alteration, the motion was agreed to.

Professor John Young, M.D., read a "Notice of the Life and Work of Sir A. C. Ramsay." [See page 256].

Mr. A. B. Motherwell exhibited (1) a number of mineral specimens, including Malachite, Argentiferous Lead, Oxide of Copper, and Calcite Crystals, from Cairns, the most northernly town in Queensland. He also showed (2) Mica Schist, showing exfoliation from lateral pressure, and (3) Strontianite, from Argyllshire.

Mr. William Jolly, F.G.S., read, on behalf of Dr. David Forsyth, Leeds, a paper entitled "The Geology of the Carsphairn District of Kirkcudbrightshire." [See page 376].

The paper was illustrated by a large series of maps, diagrams, sections, and sketches, and a collection of rock and fossil specimens. Some remarks on the district and the points touched upon by the author were afterwards made by the chairman (Mr. Young), Messrs. James Thomson, F.G.S., Dugald Bell, and other members.

Society's Rooms, 207 Bath Street, 11th February, 1892.

Mr. John Young, F.G.S., *Vice-President*, in the Chair.

Mr. William Hodge, Craigvinean, Pollokshields, was elected an Ordinary Member.

The Chairman (Mr. John Young, F.G.S.) read "A Note upon a peculiar variety of Sphærosiderite, a carbonate of iron, from the South Hill, Campsie," and exhibited specimens of the rock, also transparent sections under the Society's microscope. Mr. Young stated that this ironstone is found in connection with the strata which underlie the lower coals and limestones of the Campsie district, forming a thin band, apparently made up of an aggregation of spherical particles more or less rounded and averaging one-sixteenth of an inch in diameter. In a transparent section these particles

are seen to be composed of zonal layers of carbonate of iron segregated round a centre, in varying shades of brownish colour which mark off the layers distinctly from one another. The spheres are further distinguished by a concentric crystalline structure radiating from the centre. This combination of zonal and crystalline structure forms a lovely object for examination under the microscope, and has not apparently as yet been noted in connection with any of the other ironstones in Scotland. Its formation may probably have been due to thermal heating of the strata through igneous action.

Mr. Robert Dunlop read, on behalf of Mr. Robert M'Laren, H.M. Assistant Inspector of Mines, a note upon "A Reverse Fault in Kiltongue Coal at Drumshangie Colliery, Airdrie" [see page 390], which was illustrated by several sections. At its close remarks were made by several members, who agreed in observing that there is a more frequent occurrence of reverse faults than has been generally supposed, although they are hardly mentioned in the text-books.

Mr. John Main, F.G.S., exhibited, by the oxy-hydrogen lantern, an extensive series of Photographs of the Moon's Surface, showing numerous evidences of Volcanic Action on a large scale, and also other views of corresponding terrestrial appearances.

An interesting discussion followed, being taken part in by the Chairman (Mr. Young), Drs. Ross and Sloan, Messrs. Dunlop, Sommerville, and other members.

Society's Rooms, 207 Bath Street, 10th March, 1892.

Mr. John Young, F.G.S., *Vice-President*, in the Chair.

Mr. Dugald Bell, F.G.S., read a paper "On the Alleged Proofs of Submergence in Scotland during the Glacial Epoch.—I. Chapelhall, near Airdrie." [See page 321.]

A discussion upon various points embraced in the paper was taken part in by Messrs. Robert Dunlop, James Thomson, F.G.S., James Neilson, James Steel, and the Chairman (Mr. Young).

Society's Rooms, 207 Bath Street, 14th April, 1892.

Mr. William Jolly, F.G.S., *Vice-President*, in the Chair.

Mr. A. B. Motherwell exhibited specimens of Copal from near Ponny, on the Gold Coast of West Africa. He stated that this substance, imported for varnish-making and other purposes, is a sub-fossil gum, the product of a tree, *Trachylobium Hornemannianum*, of the old African forests, and is found at a depth of from 4 to 6 feet below the surface of the existing soil. Mr. John Young, F.G.S., also made some remarks upon the specimens.

Mr. James Neilson showed a number of specimens of Red Zeolites from the Lesser Cumbrae, in the Firth of Clyde, and read a short paper upon

their occurrence and distribution, entitled, "A Visit to the Island of Little Cumbrae, with some notes on its Minerals." [See page 373.]

The CHAIRMAN (Mr. Jolly) said that this interesting island might form a suitable locality for one of the Society's excursions next spring or summer.

Mr. M. BLAIR exhibited specimens from two large boulders near King's Cross, Arran. He remarked that the erratic blocks in this neighbourhood are very numerous, but are nearly all local, being traceable to Goatfell, 10 miles north, from which they must have crossed two deep valleys and a ridge. The two large blocks referred to are totally different from any Arran rock. From a description given by Professor Judd, in a paper on "The Secondary Rocks of Scotland" in the *Quart. Jour. Geol. Soc.*, of certain beds in the Island of Raasay, Mr. Blair thought that the rock might be found there *in situ*, and he had brought up the specimens in the hope that some of the members might be able to identify them. Prof. Judd's description is as follows:—"Conglomerates (formed of rounded or sub-angular fragments of white or purple quartzite, of Torridon sandstone, and of compact or sub-crystalline limestone) alternating with irregular lenticular beds of coarse micaceous sandstone, into which the conglomerates insensibly graduate."

The CHAIRMAN said he would endeavour, through the good offices of the schoolmaster in Raasay, to obtain specimens of the rock *in situ*, so that they might be compared with these Arran boulders.

Mr. JOHN YOUNG, F.G.S., read a joint paper by Prof. John Young, M.D., &c., and himself, "On the Root-fibres and other Processes found attached to Fronds of Carboniferous *Fenestella* and other Bryozoa." The authors in this paper referred to certain peculiar branching, fenestrated structures which they had found rooted on the fronds of *Fenestella*, and which were, apparently, as yet undescribed. These processes, when examined in thin sections, showed the same kind of finely-striated and minutely-perforated structure as that seen in the walls of the organisms from which they had grown, the true organic connection between the two being clearly seen in several of the specimens. Their external characters are, however, very dissimilar in appearance, there being no cells in the walls of the processes now described. The specimens exhibited were found in the marine limestones and shales of the Campsie, Carluke, Muirkirk, and Beith districts. The authors referred to a former joint paper, *Quart. Jour. Geol. Soc.*, vol. xxx., page 684, in which they figured and described other forms of root-like processes which they had found adherent to other fenestrated Bryozoa. Some writers had pronounced those to be distinct organisms under the name of *Palæocoryne*, but the present authors had at the time spoken of proved them to have a true organic connection with the Bryozoa on which they had grown, and later discoveries had only confirmed their statements of 1874.

The paper was illustrated by specimens, microscopic sections, and enlarged drawings of the structures.

SOCIETY'S ROOMS, 207 BATH STREET, 12TH MAY, 1892.

Mr. JOHN SMITH, *Vice-President*, in the Chair.

A most successful enlargement of a Photographic Group of the Members present at the excursion to Daleville, Braidwood, on 21st June, 1890, was presented by Mr. William Sinclair, by whom it had been originally taken, and who was cordially thanked for his gift.

The HON. SECRETARY (Mr. Murdoch) stated that since the issue of the excursion card for the season two extra excursions had been arranged, as follows:—

On 2nd July, to Bonnybridge and the Roman Wall—Mr. William Jolly, F.G.S., conductor; and on 9th July, to Balmaha, Lochlomond—Mr. James Anderson, conductor.

The HON. SECRETARY having stated a proposed arrangement by which the Transactions, &c., of Foreign Societies received in exchange by the Society were to be transferred to the Mitchell Free Library, Mr. James Thomson, F.G.S., moved that such an arrangement should forthwith be carried out. The motion was seconded by Mr. John Young, F.G.S., and unanimously agreed to. It was remitted to the Library Committee to take the necessary steps.

Messrs. James S. Cherry, Trefoil Avenue, Shawlands; Alexander Gardner, Architect, 192 Hope Street; and Alexander Laird, Merchant, 63 Wilson Street, were elected Ordinary Members.

The HON. SECRETARY (Mr. Murdoch) read, on behalf of Dr. Forster-Heddle of St. Andrews, a paper "On Pectolite and Okenite from new Localities: the former with New Appearances." [See page 241.]

Rev. A. S. WILSON, M.A., B.Sc., North Queensferry, read a paper entitled "Notes on the Geology of Fife" [see page 392], in which he gave an interesting account of the rocks of the "Kingdom," illustrating his remarks by maps and sections and by a number of rock and fossil specimens.

Remarks were afterwards made by Messrs. John Young, F.G.S., Mr. James Thomson, F.G.S., and other members.

Mr. DUGALD BELL, F.G.S., read "A short Preliminary Note on some Glacial Mounds in the neighbourhood of Lochgoil and Lochlomond." After alluding to the remarkable moraine in Glen Fruin, which he had brought under the notice of the Society rather more than a year previously, he proceeded to mention a few other accumulations of a similar kind, some of which had doubtless been already observed, though he was not aware of their having been previously notified or described.

These occur (1) at Lochgoil, near Carrick Castle, where is seen a long line or double line of large boulders and debris, extending for some distance up the glen; (2) at the head of Lochlomond, near Ardlui, shewing both lateral and terminal moraines; (3) near Balmaha, on the east side of Lochlomond, not far from its southern end, and extending in more detached portions towards the foot of the loch. The examples at (1) and (2) indicated that the respective glaciers had made a long pause at these points, and that there had been no subsequent submergence.

He then referred to the well-known instances in Glen Messan and Glen Cloy, and pointed out the important evidence which these heaps of unassorted glacial debris, found at no great height above the sea-line, furnished as to the extent and prevalence of the ice at a time when the land stood not far from its present level. He also spoke of their bearing generally on the question of the "Great Submergence."

A short discussion on various points touched upon in Mr. Bell's paper followed, being taken part in by several members. The chairman then declared the 34th session of the Society to be closed, and expressed a hope that the members would meet in the following October to carry on the work with renewed vigour.

REPORT OF THE COUNCIL FOR 1887-88.

[Read at the Annual General Business Meeting, 8th November, 1888.]

The Council have again the pleasing duty of submitting to the members their report upon the work of the past session, 1887-88, showing that the affairs of the Society have proceeded smoothly and satisfactorily.

Membership.—The membership roll has not been maintained at such a high level as could be wished, and the Council hope that members will exert themselves in this direction and bring in additions to replace the losses caused by death and removal from the district.

Finances.—As to these your Hon. Treasurer, Mr. Wight, will present his report, which will be favourable. [The Abstract of Accounts will be found at page 440.]

Meetings.—These were nine in number, and there was also a special meeting to hear a paper by the President, Sir William Thomson, F.R.S., on "Polar Ice-caps and their influence in changing Sea-levels." It was held in the Large Hall, 207 Bath Street, kindly lent by the House Committee, and there was a good attendance of members and their friends as well as of members of other scientific societies, to all of whom invitations had been given. [See vol. ix., part ii., p. 322.] The ordinary meetings were fairly, some largely, attended, and there were many papers of importance and exhibitions of specimens. [Details of these will be found in the *Transactions*, vol. viii., part ii., pages 350-58, and many of the papers will be found in the same part *in extenso*.

The Transactions.—A new part is now nearly all in type.

The Excursions of the season were as follows:—

Cathkin, on Saturday, 14th April, 1888, conducted by Mr. Walter Burns, when a visit was paid to the fine exposures of columnar traps in a quarry near Burnside, and afterwards to the Cathkin quarries; near the top of the hill were found fine specimens of volcanic ash, saponite, bowlingite, &c., &c. Some of the party proceeded across the hill to East Kilbride, taking train homewards late in the evening.

Barrhead, on Saturday, 28th April, under the guidance of Mr. D. C. Glen, F.G.S. The party first proceeded to Boyleston quarry workings in the contemporaneous traps, and were fortunate in finding some good specimens of native copper, analcite, prehnite, and other minerals. A number of the members were afterwards entertained at tea by Mrs. Glen, of Carlibar, where a pleasant evening was spent.

Corrieburn, on Saturday, 12th May, Mr. John Young, F.G.S., conductor. The excursionists proceeded to Gavell Station on the Kilsyth railway, thence walking up the slopes of the Campsie Fells to the interesting sections exposed at Corrieburn of the Carboniferous limestones, shales, ironstones, &c., with a heavy capping of Boulder-clay. Some of the old workings were afterwards visited.

Beith, on Saturday, 2nd June, conducted by Mr. Robert Craig, when the fossiliferous shales and volcanic ash-beds were intended to be visited, but the weather unfortunately was so bad that none of the members turned out.

Milngavie and Mugdock, on Saturday, 16th June, under the guidance of Mr. C. C. Bone, C.E. This excursion was taken principally to visit the spoil-heaps and tunnels along the line of the new Glasgow water supply. A number of fine specimens of volcanic rock were obtained by members.

Mid-Calder, on Saturday, 30th June, a joint-excursion with the Edinburgh Geological Society, under the leadership of Mr. James Melvin, *V.-P.*, took place, and was very successful, there being a large contingent of members from both societies.

An extra excursion which had been proposed to Balmaha, Lochlomond, did not take place, owing to the difficulty of arranging for the loch steamer to call at Balmaha at suitable times for the party.

Loss of Members.—As in every successive report, the names of some of our members have to be withdrawn from the roll through death and other causes. The most notable loss to the Society in this connection is that of Mr. David Sandeman, who had been long a member and for some years an office-bearer. Though not a contributor to the *Transactions*, he had always the interests of the Society at heart. Those of the members who cared to visit Mr. Sandeman at his home in Lenzie were sure of a hearty welcome, and an inspection of his varied collection of minerals and fossils.

The International Exhibition.—The year 1888 will long be notable in Glasgow annals for the opening and extremely successful career of the great show, which for a number of months has proved such a source of attraction to inhabitants and strangers equally. Fortunately few of the meetings of the Society took place after its opening, so that the superior attractions of the Exhibition did not interfere with the work.

Though the great collection did not contain much which was distinctly geological, there were many things which were at least kindred to the

science, such as the exhibits of industrial minerals and metallic ores, precious stones, diamond cutting, &c., &c. A very fine collection of Jade in specimens and ornamental pieces, the property of R. Novar Ferguson, M.P., which was shown in a cabinet placed in the southern approach, did not attract the attention which its merits undoubtedly deserved.

REPORT OF THE COUNCIL FOR 1888-89.

[Read at the Annual General Business Meeting, 14th November, 1889.]

The Council have again to lay before the members a report upon the work of the past year, the thirty-first of the Society's existence.

Membership.—Owing to the usual causes the membership roll has slightly diminished, which is a source of regret and anxiety to your Council, as they had hoped that the appeal made to members last year at this time would have resulted in a substantial increase.

If members would only take this matter into their serious consideration there is no reason to suppose that each one could not secure at least one new additional name either as a life- or ordinary member, and the Council hope to see that during the current session there will be a considerable accession to the roll.

The Finances, as your Hon. Treasurer, Mr. Wight, will report to you, show that the Society is in a solvent condition with a considerable balance in hand. [For the Abstract of Accounts see p. 441.]

The Meetings of the past year were nine in number—there being no special meetings—and were attended by about the usual average number of members. Plenty, sometimes a superabundance, of material was brought before them, and on several occasions papers and discussions had to be postponed to a succeeding meeting. Regarding this subject it may be pointed out to contributors of specimens or papers that if they would give some previous indication of the time they would occupy, the arrangement of the billets for the meetings would be more satisfactorily accomplished.

Nearly all the papers read during the session were illustrated by specimens, diagrams, &c., and the Council hope that most of these papers will soon be published. [See *Transactions*, vol. ix., part i, pp. 226-232.]

Two important papers, those by Mr. H. M. Cadell, F.R.S.E., and Mr. Robert Kidston, F.G.S., were delivered in the Large Hall of the Philosophical Society and the Engineers' and Shipbuilders' Society, at 207 Bath Street, and the thanks of the members are due to the House Committee for permission to use it. Members of other scientific societies and their friends were invited to both meetings, and there was a good attendance.

The Library.—There has been a fair demand for books, but probably a larger addition of new works would increase this demand. Should the state of the funds permit of the necessary expenditure, it is hoped that such an addition may be made.

Excursions.—Before the regular excursions for 1889 two special ones were arranged, as undernoted:—

Bowling, on Saturday, 23rd March, 1889, under the conductorship of Mr. W. J. Millar, C.E. On this occasion a visit was made to the excavations in Boulder-clay for the new water-works, where some fine examples of glaciated rock-surfaces were seen. Mr. Millar, who is the engineer for the works, afterwards read a detailed paper to the Society. [See *Transactions*, vol. ix., part i., p. 203.]

Ardrossan New Harbour Works, on Saturday, 6th April, conducted by Mr. Robertson, C.E., resident engineer. On the invitation of Mr. Robertson a large party of the members visited the excavations for the new works and saw some fine exposures of sandstones, shales, mudstones, and intersecting trap dykes. They also inspected the process of concrete building for the harbour walls, foundation-laying under water, &c.

The Excursions of the session were as follows:—

Cambuslang and Cathkin, on Saturday, 13th April, conducted by Mr. Walter Burns. The columnar traps and Carboniferous sandstones were first inspected, and then the party climbed Cathkin Braes to the volcanic ash-beds exposed in the old quarries near the top of the hill.

Irvine and Kilwinning, on Saturday, 27th April, conducted by Mr. John Smith. The principal part of the day's walk was to the Raised-beach beds and blown sands on the banks of Irvine water, the return journey being made *via* Kilwinning, where several exposures of Carboniferous strata were inspected.

Mugdock (Milngavie), on Saturday, 11th May, conducted by Mr. C. C. Bone, C.E. The object of the excursion was to inspect the excavations and tunnelling for the extension of the Glasgow water-works. The spoil-heaps afforded many specimens of volcanic ash, peridotite, dolerite, &c., &c.

Airdrie, on Saturday, 25th May, conducted by Mr. Robert Dunlop. An inspection was made of basalt and dolerite, finely showing spheroidal decomposition, and a remarkable exposure of a peat bed under Boulder-clay.

Cadzow Forest and Avon Water, on Saturday, 8th June, Mr. John Young, F.G.S., conductor. The members on this occasion visited the remains of the old Caledonian Forest, and saw to great advantage the Duke of Hamilton's herds of the indigenous white cattle. In the rocky banks of the Avon water some splendid exposures of Carboniferous strata were observed.

South Queensferry and the Forth Bridge, on Saturday, 22nd June, conducted by Mr. Henry M. Cadell, F.R.S.E., Hon. Sec. of the Edinburgh Geological Society. This being a joint-excursion with the members of the Edinburgh Geological Society, and

special permission having been obtained to visit the works, workshops, and the bridge itself, a very large party of members and their friends took advantage of the occasion. Leaving Queen Street Station at 1 p.m., the party changed carriages at Ratho, where they joined the Edinburgh contingent. Reaching South Queensferry about 3 p.m., they proceeded to inspect, under the guidance of some of the resident engineers, the wonderful structure now in process of being thrown across the Forth, and several of the workshops with their complicated machinery and labour-saving appliances. A considerable number of those present climbed to the top of the southern cantilever. After leaving the bridge, many of the members made an inspection of the calciferous sandstones, shale beds, and trap rocks lying along the southern shore. The party then taking train for Edinburgh proceeded to Howe's hotel, where a high tea was provided. Afterwards several toasts were given, including the prosperity of the two Societies, the health of the office-bearers and the conductor (Mr. Cadell). At 8.20 p.m. the Glasgow members left the Waverley Station, reaching Glasgow at 10.30 p.m., after a most enjoyable trip.

A new departure was taken this year in the arrangement of a walk to Hamilton Hill on Monday evening, 3rd June, to visit the fine exposures of Boulder-clay to be seen there, under the guidance of Mr. James White, *Hon. Librarian*. This excursion was much approved, and has since led to evening excursions becoming a regular feature of the season's programme.

On Saturday, 6th July, an extra excursion to Balmaha, Lochlomond, was arranged, under the conductorship of Mr. James Anderson, and was taken part in by a number of members. The conglomerate beds of the Old Red Sandstone and the dolomitic limestones were inspected, but time did not permit of anything like a full examination, and a wish was expressed that another opportunity might be given of visiting this most interesting locality.

The Transactions.—As this report shows, several valuable papers are ready, and, if possible, the printing of a new part to contain the papers of the last and the present session will be begun in January next.

Geological Photography.—From the spread of photography, owing to the comparative ease with which pictures are now taken, photographing of subjects of geological interest has become much more practicable than in former years. An invitation has been given to this Society to take part in such work by the Corresponding Societies Committee of the British Association. Your Council have looked favourably upon the suggestion, and hope that members who are practically acquainted with the subject will come forward to take part in the proposed work. Many fine rock-sections—such as are seen in quarry faces, railway cuttings, &c.—which may disappear after short intervals, might be advantageously photographed for preservation and future reference.

Loss of Members.—In all societies each year brings its own list of names of members to be added to those who have joined the *great majority*, and the one now spoken of forms no exception to the rule. Several members who were known and esteemed have been taken from amongst us, and prominent amongst these stands the name of Mathew Blair, of Paisley, who for some years served as a member of your Council. Devoted to the science, Mr. Blair was a hard working, observant student, who, had he been longer spared to us, would doubtless have done still better work than he had accomplished in the past.

REPORT OF THE COUNCIL FOR 1889-90.

[Read at the Annual General Business Meeting, 13th November, 1890.]

The Council have again to submit their report upon the work and events of the past session, the thirty-second of the Society's existence.

Membership.—For some years past it has been necessary to call attention to the fact that there has been some diminution in the roll of membership. A certain proportion of names have to be withdrawn each year owing to deaths and resignations, and the accession of new members ought to be at least as great. This has, however, not lately been the case, though for several years a form of proposal, with a request that it should be returned with a new member's name filled in, has been sent to each member. The Council would therefore ask members to make a stronger effort in the required direction.

Finances.—As on previous occasions your Hon. Treasurer, Mr. John Wight, C.A., will submit his report. It is not necessary to go into detail here, further than to say that, though upon the whole favourable, the funds of the Society are so dependent upon the membership that what affects the one re-acts upon the other. [For the Abstract of Accounts see p. 442.]

Meetings.—During the bygone session many papers and notes upon specimens of interest were submitted to the Society at its meetings, which were nine in number. [Particulars as to these will be found in the *Transactions*, vol. ix., part i., pp. 233-239.]

Excursions.—The excursions of the session were as follows:—

The Hunterian Museum, on Saturday, 12th April, 1890, under the conductorship of Mr. John Young, F.G.S., and on the invitation of Professor John Young, M.D. Those who attended were delighted with their visit, but as on a single occasion only the merest glance at the collection can be taken, a hope was expressed that further opportunities might be afforded the members of studying groups of minerals or fossils in detail.

East Kilbride, on Saturday, 26th April, under the guidance of Mr. James Anderson. This excursion took place on a fine afternoon, and when the cement-stone quarries and shale heaps were

visited, a number of interesting fossils were collected. The party after leaving East Kilbride walked to Bogton sandstone quarry, and to Braehead limestone quarry, and at Clarkston took train to Glasgow.

Nitshill, Darnley, and Barrhead, on Saturday, 10th May. Owing to the very heavy rainfall in the morning only a very limited party came out by train, and in the absence of Mr. D. C. Glen, who was prevented from attending, Mr. Murdoch, *Hon. Sec.*, conducted the party. Leaving the train at Nitshill, they first visited the sandstone quarry in the Millstone grit, worked by Messrs. Stevenson & Baird. The upper stratum, containing numberless annelid borings, was observed, also large numbers of travelled blocks which had been removed from the overlying Boulder-clay. At Darnley they inspected Mr. Kirkwood's opencast workings of the Arden cement-limestone, where a number of good specimens of fossils, &c., were got. Owing to the broken weather Barrhead was not reached.

Inverkip, Loch Thom, and Greenock, on Saturday, 24th May, under the leadership of Mr. Wm. Armour, C.E. In this excursion the equivalents of the Ballagan Beds were inspected, and afterwards some exposures of the igneous rocks of the Renfrewshire uplands.

Craigendoran and Helensburgh, on Saturday, 7th June, led by Mr. Dugald Bell. This excursion was planned to visit the cuttings for the new West Highland Railway behind Helensburgh. Some fine sections of Boulder-clay and exposures of schistose rock were met with, but it was apparent that in the course of a few months much better sections would be exposed.

Braidwood, Carluke, on Saturday, 21st June, under the conductorship of Dr. J. R. S. Hunter. This, the annual joint-excursion with the Edinburgh Geological Society, was altered from Carstairs to Braidwood on account of the kind invitation of Dr. Hunter to visit his district. After inspecting the exposures of Carboniferous strata in Braidwood Glen, the party walked to Daleville, where they were most hospitably entertained. General regret was afterwards expressed that too little time remained to inspect the treasures—geological, antiquarian, and bibliographical—stored in such profusion in Dr. Hunter's house. Unfortunately none of the members of the Edinburgh Society were present. A photograph of the party was taken by Mr. William Sinclair. [Mr. Sinclair has since presented an enlargement of this photograph to the Society.]

In addition to the usual excursions, the new departure made last year was followed up by a series of Evening Excursions on Fridays of alternate weeks, conducted by Mr. James White. They were attended with fair success, and seemed to supply a want, felt by those members who cannot

conveniently leave town on Saturdays. They were three in number, as follows :—

Hamilton Hill, north bank of Forth and Clyde Canal, on Friday, 18th April, to visit the fine section of Boulder-clay, and of the Till or *moraine profonde*, here exposed.

Bishopbriggs, on Friday, 2nd May, to inspect the thick-bedded sandstones, with local unconformity, columnar sandstone, trap dykes, &c.

Giffnock, on Friday, 16th May, to see the thick-bedded sandstones, flaggy sandstones, with numerous annelid burrows, evidences of river erosion, &c.

The Council hope that such a series will be continued next year. The thanks of the members are due to Mr. White and to the other members who kindly volunteered to conduct the various excursions.

The Library.—Your Hon. Librarian, Mr. James White, will submit his report. Few new books have been added during the year, except those received by exchange from other societies. A good many books have been taken out on the nights of meeting, showing that the Library is used by a fair proportion of the members.

The Transactions.—A new part, part i. of vol. ix., is considerably advanced at press. It will contain most of the papers read during the last two sessions, some of these being of much interest and importance.

Death of Members.—From this cause the membership roll has as usual been affected. Amongst those members who have died since last year may be noted Mr. James F. Stewart, long a member of the Society and a frequent attender of both meetings and excursions. Resident in Stirlingshire, he was locally known as the "King of Kippen." He contributed a paper to the *Transactions* "On the Occurrence of Whale Remains in the Valley of the Forth." [See vol. vi., part i., p. 49.]

Dr. Henry Muirhead, of Busheyhill, was a life member of the Society, but his energies were so devoted to the interests of the Philosophical Society that he had little time to spare for geology, though he had always a warm side for the wellbeing of our Society.

The name of Dr. Milne Home, though not a member of the Society, may be mentioned in this connection for his work in general geology, but more especially as regards his papers on the distribution of boulders, in his capacity of Chairman of the Boulder Committee of the Royal Society of Edinburgh. His death will be much regretted by all Scottish geologists.

REPORT OF THE COUNCIL FOR 1890-91.

Read at the Annual General Business Meeting, 12th November, 1891.]

Your Council have again to lay before you their annual report upon the condition and work of the Society during the past year, and regarding which they have upon the whole to speak favourably.

The MEMBERSHIP has not more than held its own during the year; and as it was a twelvemonth ago less than it had previously been for some time, the Council are disappointed to find that a greater effort has not been made to increase it. Circulars calling attention to this fact, with proposal forms, have been time after time sent to every member, with a very small response. It may therefore be again pointed out how desirable it would be if each member would undertake to find one each additional new member, and how much the objects of the Society would thereby be promoted.

The MEETINGS of the session were nine in number, and had a fair, though not a numerous, attendance. There was brought forward quite sufficient material, both in papers and specimens, to occupy all the available time.

[The titles of the various papers and notices of specimens will be found at pp. 414-422.]

The EXCURSIONS of the spring and summer were as follows:—

Mugdock, on Saturday, 18th April, 1891, conducted by Mr. C. C. Bone, C.E. Sections at cuttings for the great new reservoir of the Glasgow Waterworks were visited, and afterwards the spoil-heaps from the tunnel excavations.

Nettlehirst and Auchenmade, Beith, on Saturday, 2nd May, conducted by Mr. Robert Craig, *cor. mem.* The weather proved so extremely bad that this excursion, planned to visit the Lower Carboniferous limestone strata of this district, did not come off, not a single member having arrived from Glasgow.

Croy and Barrhill, on Saturday, 16th May, conducted by Mr. William Jolly, F.G.S. Sections of intrusive dolerite were seen, and a visit was paid to the gannister beds. A portion of the Antonine Roman Wall was afterwards gone over, and recent investigations were explained by the leader to a numerous party.

Dalry, on Saturday, 30th May, conducted by Mr. John Smith. Some good sections of limestones and shales on Caaf water were seen, also exposures of clayband ironstones, &c.

Murroch and Auchenreoch Glens, on Saturday, 13th June, conducted by Mr. John Renwick. Some fine examples of volcanic disturbance were seen, also of denudation of the calciferous sandstones and limestones. In the latter glen was passed the remarkable dyke which, crossing at right angles, has been breached by the stream. From its bared sides and considerable height it is locally known as the "Gates of Sodom." From here the party struck across the moorland for Dumbarton.

Tory Glen, Chapelhall, on Saturday, 27th June, conducted by Mr. Robert Dunlop. The day being fine a large party, including members of the local Natural History Society, met at Airdrie station and walked to Chapelhall, east of the town. Chapelhall is said to have received its name from the fact that while sinking a pit shaft here the workmen came upon an old chapel and burial ground. In a sandstone quarry a fine section of

the upper coal measures was seen, containing the main coal seam of 9 feet. About 500 yards south of this occurs the well-known glacial shell-bed, containing arctic shells—the highest present known horizon in this district for their occurrence. Further along the bed of the stream was seen an immense dyke of basalt, which stretches for some distance east and west. A fault here brings the Lower Carboniferous measures to the same horizon as the upper coals—a dislocation of from 1000 to 2000 feet. Continuing up the glen the party examined a number of pot-holes in the rock of the river-bed, smooth, circular cavities of from one to two feet deep. Among the shales here were got some good specimens of teeth and scales of *Rhizodus Hibberti*, one of the Carboniferous sauroid fishes. From this the party proceeded to the Fairy Glen, where Samson's Putting Stone—a dolerite boulder of above 12 tons weight—was seen. The route was then taken via Newhouse to Airdrie where the party were entertained to tea by the Airdrie Natural History Society—Mr. A. B. Motherwell occupying the chair. The Glasgow members then took train for Queen Street Station.

In pursuance of the arrangements made last year, the following Evening Excursions were taken :—

Cessnock New Dock, on Friday, 10th April, conducted by Mr. A. Hamilton, to visit the sections in sand and clay presently exposed.

Hamilton Hill and Sheepmount, on Friday, 8th May, conducted by Mr. James White, Hon. Librarian, to inspect the fine sections of Boulder-clay, &c.

Botanic Gardens and Kirklee, on Friday, 22nd May, conducted by Mr. James White, to visit the cuttings for the new Central District Railway through sandstone, Boulder-clay, &c.

Pollokshaws, on Friday, 5th June, conducted, in Mr. Murdoch's absence, by Mr. James White, to visit the sections of Boulder-clay in the cuttings of the new Cathcart Railway.

The thanks of the members are due to all the gentlemen who kindly took charge of the various excursions of the season, both afternoon and evening.

A proposal was made early in the year that the conductors should draw up a short account of each excursion suitable for publication. This was done in several instances, but it is hoped that in another year the practice will be more generally followed.

For the first time for a number of years no joint-excursion with the members of the Edinburgh Geological Society was arranged. No reason can be assigned for this, unless it be that no excursions were made by the members of that Society this year. It is to be hoped that such pleasant joint gatherings as took place annually for a number of years will again be resumed.

The LIBRARY remains without any material change. It was not thought

advisable to spend much money in new books, but perhaps a grant may be arranged this year.

The Transactions.—The first part of a new volume, part i. of vol. ix., was issued to members in April last. Very complimentary notices of the contents were given in the *Scotsman*, *Glasgow Herald*, and elsewhere, one of them stating that the Society's work, as shown in this part, was second to that of no society out of London.

The Finances of the Society will be spoken of in the Treasurer's report. The Abstract of Accounts is printed with the circular calling the present meeting [November, 1891], and will be found at page 443.

The Corresponding Societies Committee of the British Association.—For a number of years past the Society has been placed on the list of Corresponding Societies with the privilege of sending a delegate to the British Association meeting, who is *ex officio* a member of the General Council of that body. It may be shortly stated that the object of this committee is to bring all provincial scientific societies into closer union for the purpose of following out some common subjects of investigation. One of these, open to members of this society, is Geological Photography, and another the recording and preserving of notable Erratic Blocks scattered over the country, and in both of these the Council hope that members will be willing to give their help.

The Loss of Members is unfortunately a line which can never be omitted. Each annual report has to deplore the removal of some good and true friends of the Society, and the present is no exception. Prominent in this connection are the names of two members of Council which occur side by side in one of the committees for the past year, Walter Burns and Daniel Macmillan. Both were interested and active in the Society's work, and both will be much missed from the meetings and excursions, of which they were most regular attenders. Neither of them of very advanced years, they rapidly fell into feeble health, and in a comparatively short time were called away. The Society will not easily find two members more anxious to serve its interests in every way.

Another member removed by death during the session was Mr. Robert Mason, F.L.S., long an office-bearer and a constant attender of the meetings and excursions. He was for many years the honorary secretary of the Natural History Society of Glasgow. Mr. Mason had formed a large collection of minute fossil organisms from the weathering of the Carboniferous limestones and shales of the West of Scotland, mounting them in slides for the microscope. From these he exhibited selections at various meetings. Since his death Mr. Mason's fine cabinet of specimens has passed into the hands of Dr. J. R. S. Hunter of Daleville, Carluke, to become an adjunct of the "Braidwood Collection."

ABSTRACT OF THE TREASURER'S ACCOUNTS FOR YEAR ENDING 30TH SEPTEMBER, 1888.

CASH ACCOUNT.

RECEIPTS.

Balance—Due by Treasurer at close of last Account,			£4 0 0
Annual Subscriptions—			
Subscriptions for current year,	£72 0 0		
New Members,	6 10 0		
Arrears,	3 0 0		
		81 10 0	
Interest on invested funds,			6 12 1
Publications and Catalogues sold,			2 10 5½
			£94 12 6½

EXPENDITURE.

Transactions—Balance of Account,			£2 8 0
Catalogue—Balance of Account,			6 17 0
Rent, Insurance, and Attendance,	£14 11 6		
Collector's Commission and Petty Charges,	4 1 11		
Printing Circulars and Receipt Book,	11 8 3		
Disbursements by Secretaries and Librarian,	9 17 3½		
Palæontographical Society,	1 1 0		
Reporting Sir William Thomson's Lecture,	2 10 0		
		43 9 11½	
New Books, Maps, and Binding,		12 2 10	
Cash in Bank on Deposit Receipt,	£25 0 0		
Cash in Treasurer's hands,	4 14 9		
		29 14 9	
			£94 12 6½

STOCK ACCOUNT.

To Balance to Credit,			£461 14 9
			£461 14 9

By Funds—Corporation Loan,	£170 0 0		
Cash in Bank and in hand,	29 14 9		
		£199 14 9	
Property—			
Books,	£165 0 0		
Transactions,	55 0 0		
Furniture and Microscope,	42 0 0		
Fossils (not valued),	0 0 0		
		262 0 0	
		£461 14 9	

CASH ACCOUNT.

RECEIPTS.				EXPENDITURE.					
Balance on hand and in Bank at close of last Account,	£29	14	9	Printing *Transactions*,	£56	4	0		
Subscriptions for current year, and Arrears (£2),	76	0	0	Woodcuts and Plates,	10	1	0		
Interest,	7	2	3	Articles Reprinted,	10	12	6		
Publications sold,	1	10	7					£76	17 6
Balance due to the Treasurer,	2	13	4	Rent, Insurance, and Attendance,	£12	11	6		
				Collector's Commission and petty charges,	3	18	11		
				Printing Circulars and Receipts,	9	4	0		
				Disbursements by Secretaries and Librarian,	10	1	1		
				Subscription to Palæontographical Society,	1	1	0		
								36	16 6
				New Books and Bookbinding,				3	6 11
	£117	0	11					£117	0 11

STOCK ACCOUNT.

To Balance to credit,	£414	6	8	By Funds Invested, *less* due to Treasurer,				£167	6 8
				Property—					
				Books,	£165	0	0		
				Transactions,	40	0	0		
				Furniture,	22	0	0		
				Fossils, not valued,	0	0	0		
				Microscope,	20	0	0		
								247	0 0
	£414	6	8					£414	6 8

ABSTRACT OF TREASURER'S ACCOUNTS FOR YEAR ENDING 30TH SEPTEMBER, 1890.

CASH ACCOUNT.

RECEIPTS.

Subscriptions for current year, and Arrears (£3),	£73	0	0
Life Membership Subscription,	5	5	0
Interest,	7	5	2
Publications sold,	1	7	0
Petty Receipts,	0	19	6
	£87	16	8

EXPENDITURE.

Balance due to the Treasurer,					£2	13	4
Rent, Insurance, and Attendance,	£12	10	0				
Collector's Commission and petty charges,	6	4	8				
Circulars, Receipts, and Minute Book,	7	4	0				
Disbursements by Secretaries and Librarian,	8	9	11				
Subscription to Palæontographical Society,	1	1	0				
				35	9	7
Binding Books,				0	17	4
Cash in Bank,	£50	0	0				
Less Balance due to the Treasurer,	1	3	7				
				48	16	5
				£87	16	8

STOCK ACCOUNT.

To Balance to credit,				£718	16	5
				£718	16	5

By Funds Invested, *less* due to the Treasurer,				£218	16	5
Property—						
Books,	£440	0	0			
Furniture, Bookcases, and Microscope,	60	0	0			
Fossils, not valued,	0	0	0			
				500	0	0
				£718	16	5

CASH ACCOUNT.

RECEIPTS.				EXPENDITURE.				
Cash in Bank,	£50 0 0			Plates for *Transactions*,			£7 13 0	
Less due to the Treasurer,	1 3 7			Printing *Transactions*, to account,			50 0 0	
		£48 16 5		Rent, Insurance, and Attendance,	£12 10 0			
Subscriptions for current year, and Arrears (£2),		73 0 0		Collector's Commission and petty charges,	3 15 0			
Interest,		7 16 4		Printing Circulars, &c.,	6 13 6			
Publications sold,		1 14 3		Disbursements by Secretaries and Librarian,	13 8 9			
				Subscription to Palæontographical Society,	1 1 0			
						37 8 3		
				New Books and Binding,		4 8 2		
				Cash in Bank,	£30 0 0			
				Do. in Treasurer's hand,	1 17 7			
						31 17 7		
		£131 7 0				£131 7 0		

STOCK ACCOUNT.

To Balance to Credit,	£701 17 7		By Cash in Bank and on hand,			£31 17 7	
			Funds invested,			170 0 0	
			Property—				
			Books,	£440 0 0			
			Furniture, Bookcases, and Microscope,	60 0 0			
			Fossils (not valued),	0 0 0			
					500 0 0		
	£701 17 7				£701 17 7		

THE GEOLOGICAL SOCIETY OF GLASGOW.

(INSTITUTED 1858.)

OFFICE-BEARERS FOR SESSION 1892-93.

President—LORD KELVIN, LL.D., *P.*R.S., &c.

Vice-Presidents.

For Three Years.	*For Two Years.*	*For One Year.*
Wm. Armour, C.E.	John Smith.	Wm. Jolly, F.G.S.

Council.

Jno. Young, LL.D., F.G.S.	J. Sommerville.	D. Bell, F.G.S.
James Anderson.	James Steel.	John Renwick.
John Main, F.G.S.	C. L. Dobbie.	Dr. S. Sloan.
Wm. Sinclair.	James S. M'Lennan.	Ex-Provost Clark.

Hon. Treasurer—John Wight, C.A., 150 Hope Street.

Hon. Librarian—James White, 56 Rose Street, Garnethill.

Hon. Secretary and Editor of Transactions—James B. Murdoch, F.R.Ph.S.E., Capelrig, Mearns.

Assistant Hon. Secretary—Gavin M. Pratt, 133 West Campbell Street.

Publishing Committee.

John Young.	Dugald Bell.	Gavin M. Pratt.
Wm. Jolly.	William Sinclair.	J. B. Murdoch, *Convener.*

Library and Museum Committee.

J. Sommerville.	J. Anderson.	J. S. M'Lennan.
J. Renwick.	John Main.	J. Wight, C.A.
James Steel.	William Armour.	Jas. White, *Convener.*

Finance Committee.

Dugald Bell.	C. L. Dobbie.
Dr. Sloan.	John Wight, *Convener.*

Excursion Committee.

Dugald Bell.	Gavin M. Pratt.	James White.
James Steel.	J. Sommerville.	J. Renwick, *Convener.*

Auditors.

David Pearson.	J. Dougan.

LIST OF MEMBERS, March, 1893.

Honorary Members.

Year of Election.

1865. Geikie, Sir Archibald, LL.D., F.R.S., F.G.S., Director-General of the Geological Survey of Great Britain and Ireland, Museum, Jermyn Street, London, W.

1867. Jones, Professor T. Rupert, F.R.S., F.G.S., 10 Ulverdale Road, King's Road, Chelsea, London, S.W.

1867. Kirkby, James W., Kirkland, Leven, Fifeshire.

1867. Woodward, Henry, LL.D., F.G.S., British Museum, Natural History Department, South Kensington, London, S.W.

1867. M'Chesney, Joseph H., Professor of Geology, University of Chicago, U.S.

1871. Hull, Edward, F.G.S., late Director of the Geological Survey of Ireland, 20 Arundel Gardens, Notting Hill, London, W.

1872. Kelvin, Right Hon. Lord, LL.D., *P.*R.S., Professor of Natural Philosophy, University of Glasgow, *President.*

1872. Young, John, M.D., Professor of Natural History, University of Glasgow.

1879. Hunter, John R. S., LL.D., Daleville, Braidwood, Carluke. [1864]*

1883. Judd, J. W., F.R.S., F.G.S., Science Schools, South Kensington, London, S.W.

1883. Brown, Robert, M.D., F.G.S., Fersley, Rydal Road, Streatham, London, S.W.

1885. Heddle, M. Foster, M.D., F.R.S.E., late Professor of Chemistry and Mineralogy, St. Andrews.

1888. Murray, John, LL.D., F.R.S.E. (of the "Challenger"), 15 Frederick Street, Edinburgh.

1889. Argyll, His Grace the Duke of, Inverary Castle, Inverary.

Honorary Associates.

1867. Struthers, Thomas, 2 Gilmore Terrace Upper, Edinburgh. [1859]

1871. Crosskey, Rev. Henry W., LL.D., F.G.S., 17 Gough Road, Edgbaston, Birmingham. [1858]

* The date *after* a name is that of election as an ordinary member.

Year of Election.

1871. Horne, James, London. [1858]
1871. Farie, James, Canonbury, London. [1859]
1878. Lapworth, Charles, LL.D., F.G.S., Professor of Geology, Sir Josiah Mason College of Science, Birmingham.
1881. Wünsch, E. A., F.G.S., Carharrack, Scarrier, Cornwall. [1858]
1883. Traquair, R. H., M.D., F.R.S.E., F.G.S., Museum of Science and Art, Edinburgh.
1883. Geikie, James, LL.D., F.R.S.E., F.G.S., Professor of Geology and Mineralogy, University of Edinburgh. [1873]
1886. Robertson, David, F.L.S., F.G.S., Fern Bank, Millport. [1867]

Corresponding Members.

1859. Dougall, Professor John, M.D., 6 Belmar Terrace, Pollokshields, Glasgow.
1860. Sommerville, George, Thornliebank.
1862. Hunter, James, Ironmaster, Coltness.
1864. Mitchell, Rev. Hugh, LL.D., Craig, Montrose.
1865. Winchell, Alex., Professor of Geology, University of Michigan, U.S.
1866. Gloag, Rev. Dr. Paton J., late of the Manse, Galashiels.
1866. Myers, Rev. Edward, F.G.S., 20 Summerhill Terrace, Birmingham.
1867. Craig, Robert, King Cottage, Beith.
1867. Gordon, Rev. Dr., Manse of Birnie, Elgin.
1867. Kerr, David, Markinch, Fifeshire.
1871. Jack, R. L., F.G.S., Government Geologist, Elizabeth Street, Brisbane, Queensland.
1871. Jamieson, T. F., F.G.S., Ellon, Aberdeenshire.
1871. Kinahan, G. H., late of the Geological Survey of Ireland, Dublin.
1871. Ward, John, F.G.S., 23 Stafford Street, Longtown, Staffordshire.
1878. Stewart, Rev. Alex., LL.D., F.S.A.Scot., Ballachulish Manse, Nether-Lochaber.
1883. Lindström, Professor G., State Museum, Stockholm, Sweden.
1883. Scott, Thomas, 14 Lorne Street, Leith Walk, Edinburgh. [1880]
1883. Smith, W. Anderson, Ledaig.
1884. Dobbie, J. J., M.A., D.Sc., Professor of Chemistry and Geology, University College, Bangor, North Wales. [1876]
1884. Nathorst, Dr. Alfred Gabriel, Geological Survey Office, Stockholm, Sweden.
1887. Naismith, Thos., 6 Broompark Terrace, Dennistoun, Glasgow. [1861]
1893. Stewart, Thomas, Yarraville, Australia, c/o James Stewart, Netherby, Stonehaven. [1878]

Year of Election.

Ordinary and Life Members.

1868. Allan, Archibald B., C.E., Hillock House, Govan Road, Govan.
1882. Anderson, James, 76 West Howard Street, Glasgow.
1881. Armour, William, C.E., 207 West George Street, Glasgow, *Vice-President.*

1875.*Bain, Sir James, 3 Park Terrace, Glasgow.
1867. Bannerman, David, 9 Waterloo Street, Glasgow.
1891. Barnett, James Rennie, Lilybank House, Johnstone.
1858.*Barr, Thomas M., C.E., Caledonian Railway, Perth. [1881]†
1858. Bell, Dugald, F.G.S., 27 Lansdowne Crescent, Glasgow.
1859. Bennie, James, Geological Survey of Scotland, Edinburgh.
1892. Blackwood, Bailie James, Gillsland, Kilmarnock.
1889. Blair, Matthew, 11 Hampton Court Terrace, Garnethill, Glasgow.
1887. Boyd, John, 9 Prince's Square, Regent Park, Glasgow.
1882. Brand, John, 81 Gloucester Street, Glasgow.
1887. Brown, Andrew, 27 Roselea Drive, Dennistoun, Glasgow.
1883. Brown, George S., B.Sc., 19 Windsor Street, Glasgow.
1892. Brown, John Arthur, Dowanhill Gardens, Glasgow.
1890. Brownlie, Robert, 8 Ardgowan Terrace, Sandyford, Glasgow.
1892.*Buchan, W. P., Fairyknowe, Cambuslang.
1877. Buchanan, John, 230 Duke Street, Glasgow.
1888. Burnet, J. M., Duncairn Villa, Crosshill, Glasgow.
1866. Burnet, John, 167 St. Vincent Street, Glasgow.

1892. Caldwell, Hugh, The Braes, Bridge of Weir.
1873. Cameron, Robert, Wellpark House, Bathgate.
1877. Campbell, John MacNaught, Kelvingrove Museum, Glasgow.
1880. Carmichael, Robert S., Audit Office, St. Enoch Station, Glasgow.
1891. Carson, John, 6 Doune Quadrant, Kelvinside, Glasgow.
1890. Chalmers, John, 15 Iona Place, Mount Florida, Glasgow.
1892. Cherry, James S., Trefoil Avenue, Shawlands, Glasgow.
1888. Clark, Ex-Provost, Chapel House, Paisley.
1875.*Clavering, Thomas, 27 St. Vincent Place, Glasgow.
1883. Cleland, John, B.Sc., C.E., Woodhead Cottage, Old Monkland.
1875.*Collins, Sir William, 3 Park Terrace, East, Glasgow.
1866. Connal, Sir Michael, Virginia Buildings, Glasgow.
1891. Cowie, Charles, Woodend, Partick.
1874. Cox, C. C., Castle Street, Barnstaple.

* Life Members. †A date *after* the names of Ordinary Members is that of their election as Life Members.

Year of Election.

1877.*Dansken, John, 121 West Regent Street, Glasgow.
1874. Darling, George E., 178 St. Vincent Street, Glasgow.
1881. Dickson, John, 196 Parliamentary Road, Glasgow.
1883.*Dobbie, Charles Lizars, 21 St. James Street, Hillhead, Glasgow.
1886. Dobbie, Rev. R. W., 17 Broompark Drive, Dennistoun, Glasgow.
1881.*Dougan, John, 13 Leven Street, Pollokshields, Glasgow.
1889. Douglas, William, Golconda, Kilwinning.
1888. Dow, Walter, Bekeni, Dalziel Drive, Pollokshields, Glasgow.
1887. Dow, Wm., 165 Hospital Street, Glasgow.
1867. Drew, Alexander, 15 Nicholas Street, Manchester.
1883. Dunlop, Robert, Whiterigg, Airdrie.
1868. Dunn, William, 183 West George Street, Glasgow.

1884. Edmiston, James, 297 Argyle Street, Glasgow.

1872.*Farquhar, Ex-Bailie John, 13 Belhaven Terrace, Hillhead, Glasgow.
1872. Forsyth, David, M.A., D.Sc., Higher Grade School, Leeds.

1866. Gale, James M., C.E., Corporation Water Works, Glasgow.
1892. Gardner, Alexander, 192 Hope Street, Glasgow.
1887. Gardner, John, 21 Clyde Place, Glasgow.
1884. Gill, Robert, 109 West George Street, Glasgow.
1873.*Gilmour, Thomas, M.D., Port Ellen, Islay. [1878]
1879. Graham, Alex. M., 20 Dixon Street, Glasgow.
1888. Graham, James D., M.A., Ayr Grammar School, Ayr.
1877. Graham, M. M., 21 Bath Street, Glasgow.
1866. Grant, James, 8 Queen's Terrace, Glasgow.
1881. Gray, Harry, 15 Newton Terrace, Glasgow.
1886. Guy, Robert, 120 West Regent Street, Glasgow.

1890. Hair, Wm. B., 5 Mansfield Place, West Regent Street, Glasgow.
1872. Hamilton, Archibald, C.E., Clyde Navigation Office, Robertson Street, Glasgow.
1880. Harvie, John, Clydesdale Bank, 30 St. Vincent Place, Glasgow.
1885. Henderson, George G., M.A., Andersonian Buildings, 204 George Street, Glasgow.
1880. Henderson, James, M.A., Whitehill School, Dennistoun, Glasgow.
1876. Henderson, John, 8 Cecil Place, Paisley Road, Glasgow.
1893. Hogg, R. M., Teacher, Irvine.
1886. Hewett, H. S., 8 Milton Terrace, Langside.
1877. Hill, Thomas N., 140 Bath Street, Glasgow.

Year of Election.

1877. Hislop, George R., F.C.S., F.R.S.S.E., Corporation Gas Works, Paisley.
1891. Hodge, William, 27 Montgomerie Drive, Kelvinside, Glasgow.
1892. Hodge, Wm., Craigvinean, Nithsdale Drive, Pollokshields, Glasgow.
1870. Horne, R. R., Mount Vernon Colliery, Tollcross.
1884. Howat, John, 527 New City Road, Glasgow.
1866. Hunt, Edmund, C.E., 87 St. Vincent Street, Glasgow.

1890. Johnstone, Ronald H., 75 West Nile Street, Glasgow.
1884. Jolly, William, F.R.S.E., F.G.S., Greenhead House, Govan, *Vice-President.*

1870.*Ker, William, 1 High Windsor Terrace, Glasgow.
1877. Kerr, Charles James, Greenfaulds House, Cumbernauld.
1890. Kidston, Robert, F.G.S., 24 Victoria Place, Stirling.
1877. Kincaid, Thomas, 9 Lansdowne Crescent, Glasgow.
1882. King, Hugh B., Kilwinning, Ayrshire.
1882. King, Robert C., C.A., Kilwinning, Ayrshire.
1874. King, Thomas, 110 Hill Street, Garnethill, Glasgow.
1860. Kirsop, John, 98 Argyle Street, Glasgow.
1867. Knox, Adam, 10 Clayton Terrace, Dennistoun, Glasgow.
1872. Knox, John, 58 Bath Street, Glasgow.

1892. Laird, Alexander, 63 Wilson Street, Glasgow.
1883. Laird, Andrew, C.E., 123 St. Vincent Street, Glasgow.

1874.*Lamb, Thomas, 190 Parliamentary Road, Glasgow.
1880. Lucas, William, 133 West George Street, Glasgow.
1892. Lusk, Hugh D., Rosebank, Forsyth Street, Greenock.

1866. M'Clelland, Andrew S., C.A., 115 St. Vincent Street, Glasgow.
1889. M'Creath, George W., M.E., 208 St. Vincent Street, Glasgow.
1884. M'Donald, A. B., C.E., 64 Cochrane Street, Glasgow.
1890. M'Ewan, William, 148 Bothwell Street, Glasgow.
1892. M'Farlane, John R., 22 Royal Exchange Square, Glasgow.
1867. M'Glashan, John, 114 Candleriggs, Glasgow.
1882. Mackintosh, Rev. John, The Manse, Uddingston.
1888. M'Intosh, Very Rev. Canon, Airdrie.
1888. Macintyre, Duncan, North Public School, Alexandria.
1886. M'Laren, Robert, Bonny, Gardenside, Uddingston.
1881.*Maclay, David J., 3 Woodlands Terrace, Glasgow.
1877. M'Lay, William, 11 May Terrace, Mount Florida, Glasgow.

Year of Election.

1882. M'Lennan, James S., Oswald Public School, Knightswood, Maryhill.
1883. M'Whirr, John, 10 Kilmailing Terrace, Cathcart.
1887. Main, John, F.G.S., 21 Hartington Gardens, Dowanhill, Glasgow.
1874. Marshall, Robert, 97 Wellington Street, Glasgow.
1887. Meiklejohn, Andrew, 3 Windsor Street, Glasgow.
1867. Millar, John (J. Black, Drew, & Co.), 23 Royal Exchange Square, Glasgow.
1877. Millar, W. J., C.E., 261 West George Street, Glasgow.
1892. Miller, William, 1 Stanmore Terrace, Mount Florida, Glasgow.
1881. Mitchell, G. A., 67 West Nile Street, Glasgow.
1887. Mitchell, Robert, 24 Howard Street, Bridgeton, Glasgow.
1885. More, Robert, 505 Sauchiehall Street, Glasgow.
1877. Moore, Robert T., C.E., B.Sc., 158 St. Vincent Street, Glasgow.
1889. Motherwell, A. B., British Linen Bank, Airdrie.
1859. Murdoch, James B., F.R.Ph.S.E., Capelrig, Mearns, Renfrewshire, *Honorary Secretary.*
1875. Murdoch, William, 11 Bothwell Street, Glasgow.
1870.*Murray, David, LL.D., 169 West George Street, Glasgow.

1865. Napier, J. W., Woodielea, 14 Windsor Circus, Glasgow.
1891. Neilson, James, High Crosshill, Rutherglen.
1868. Neilson, Richard, 33 Virginia Street, Glasgow.
1867. Norman, John, 131 St. Vincent Street, Glasgow.

1869. Orr, John, 12 Newhall Terrace, Glasgow.

1890. Parker, T. Carter, Clare House, Huddersfield.
1889. Parker, Wm. Ernest, Middle Class School, Barnstaple.
1875. Pearson, D., 15 Carnarvon Street, Glasgow.
1891. Pollock, Arthur, Kirkland, Bonhill, Dumbartonshire.
1877. Pratt, Gavin M., 104 West Graham Street, Glasgow, *Assistant Hon. Secretary.*

1873. Rankine, David, C.E., 75 West Nile Street, Glasgow.
1880. Reid, James A. (of M'Grigor, Donald, & Co.), 172 St. Vincent Street, Glasgow.
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